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AUTHOR Meinhard, Richard
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ABSTRACT

This design proposal for "Schools of the Marketplace" describes a system that does not rely on government bureaucracy to operate. Instead, it allows parents and students to choose their teachers, evaluates student performance more on results of projects and papers than on standardized tests, empowers teachers to form professional groups rather than depend entirely on unions, and takes advantage of a new entity--the Educational Development Corporation--to both guide and profit from the enterprise of education. The first of seven parts in the design plan addresses the intended outcomes through student, teacher, and organizational development. The second part outlines the basic concept, organization, finance and governance, and design of marketplace schools. The third part outlines the design team and its qualifications, and the fourth part gives the theoretical bases. The fifth part considers budget, and evaluation of marketplace schools is described in part 6. The final part gives the strategy for convincing others to put this design in place. Supporting documents include a paper entitled "Time to Shift the Paradigm," by Michael Rothschild, which addresses bionomics; and three papers by Richard Meinhard: "A Developmental Baseline Profile of 12 Key Elementary Science Concepts/Processes," "Concept/Process-Based Science," and "Contributions of Piaget to Science Education." (RR)

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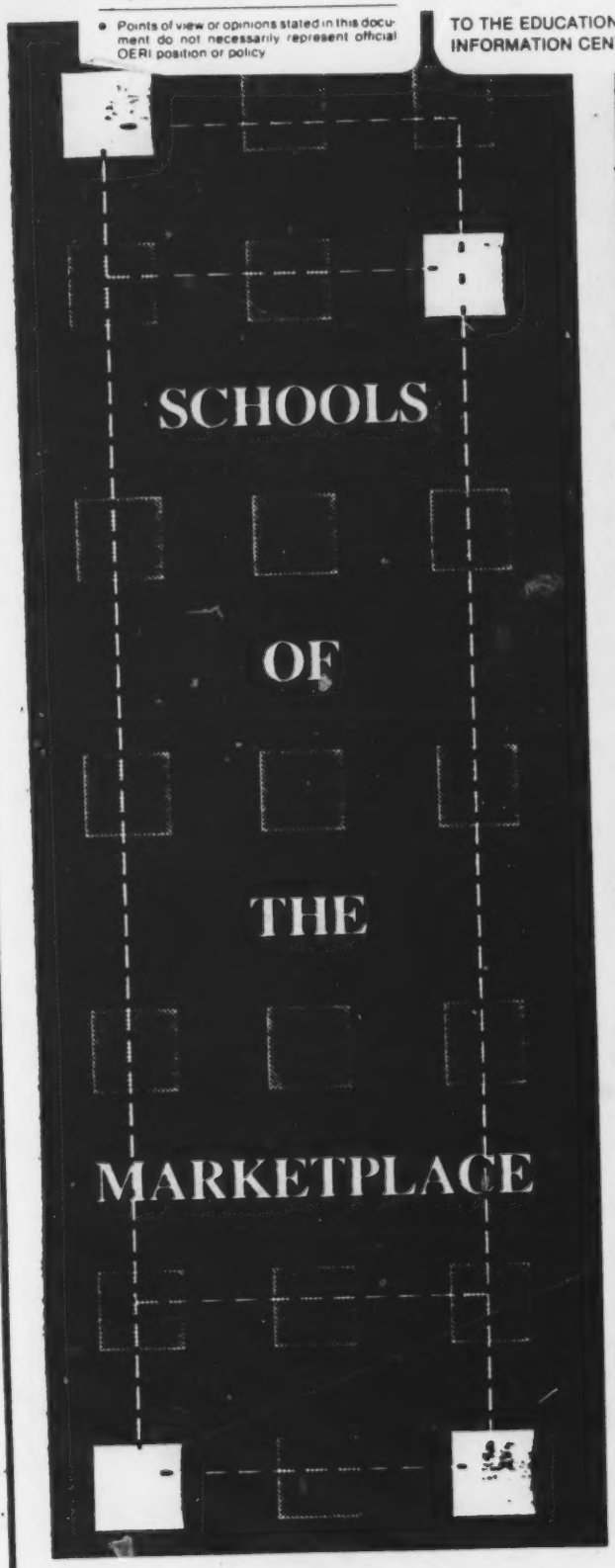

SCHOOLS OF THE MARKETPLACE

A New Generation of American Schools

If we value the pursuit of knowledge, we must be free to follow wherever that search may lead us. The free market is a barking dog, to be tethered on as short a chain.

Allan E. Stevenson, Jr.

Prepared for
New American Schools
Development Corporation

By
Cascade Policy Institute
and
Institute for Developmental Sciences
Portland, Oregon

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Schools of the Marketplace

A Proposal to the New American Schools Development Corporation

by

Richard Meinhard, Ph.D.
INSTITUTE FOR DEVELOPMENTAL SCIENCES

for

CASCADE POLICY INSTITUTE

Portland, Oregon
February 14, 1992

CASCADE POLICY INSTITUTE

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Portland, Oregon 97205
(503) 242-0900
Fax (503) 242-3822

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CASCADE POLICY INSTITUTE

(503) 242-0900

Steve Buckstein
President

Tracie Sharp
Program Director

William Udy
Finance Director

Schools of the Marketplace

PREFACE

This design proposal for *Schools of the Marketplace* was stimulated by the innovative Request for Proposals from the **New American Schools Development Corporation** (NASDC). In 1990 President Bush and the governors adopted six ambitious education goals involving early childhood, the graduation rate, academics, science and math, adult literacy, and drugs and violence. President Bush planned a four part education strategy, **America 2000**, to carry out these goals. Strategy two calls for the design of **New American Schools**. In 1991 NASDC was formed by American business as an independent, non-profit, limited life corporation to issue contract awards for the design of break-the-mold New American Schools. NASDC is raising up to $200 million to support a number of design teams organized to create and test designs for schools. These schools will achieve national education goals and meet world class standards for all students and help these students leave school prepared for responsible citizenship, further learning, and productive employment. NASDC will assist communities across the nation to adopt and recreate these designs for their own purposes.

Schools of the Marketplace describes a system that doesn't rely on government bureaucracy to operate. Instead, it allows parents and students to choose their teachers; evaluates student performance more on the results of projects and papers than on standardized tests; empowers teachers to form professional groups rather than depend entirely on unions; and takes advantage of a new entity—the **Educational Development Corporation**—to both guide and profit from the enterprise of education.

Schools of the Marketplace forms a new "educational ecosystem" which will harness market power to achieve world class results. It incorporates Rothschild's Bionomic model of self-organizing human systems, and Piaget's explanations of how we construct knowledge. Both are well-founded in theory and practice but haven't been allowed to operate in American education. They empower individuals and allow human organizations to become self-creating and self-duplicating.

The **Cascade Policy Institute** and the **Institute for Developmental Sciences** find the idea of designing break-the-mold schools intriguing and of great value in helping stimulate deeper discussion about the roots of education problems. **Cascade Policy Institute** is a nonprofit think tank dedicated to exploring voluntary, private sector answers to public policy questions facing Oregon and the nation. Respecting market mechanisms and individual liberty, Cascade looks for better ways to educate America's children than are possible within a bureaucratic public school monopoly.

Cascade contracted with the **Institute for Developmental Sciences** (IDS) and its executive director, Richard Meinhard, Ph.D., to develop this proposal for NASDC. IDS is a nonprofit research and development organization devoted to the scientific study of student,

813 SW Alder, Suite 707 Portland, Oregon 97205

teacher, and program development in education. Dr. Meinhard wrote a piece published in the August 22, 1991 *Wall Street Journal* for **Cascade Policy Institute** entitled "Education by Committee in Oregon." It analyzed Oregon's recently enacted legislation, the "Education Act for the 21st Century", and concluded it fell into the "bureaucratic trap of good intentions."

Even the design process in *Schools of the Marketplace* is unusual. It is a contract system which opens up the design effort to draw in a wide variety of educational innovators and leaders. Three public schools in Oregon and Washington have agreed to act as initial lab sites for the **site-based design process.** Additional sites will be added and new *Schools of the Marketplace* started to test the completed design. The success of *Schools of the Marketplace*, their students, and the Educational Development Corporation will be duplicated by others nationwide not by political or bureaucratic means, but through marketplace mechanisms including the profit motive.

Schools of the Marketplace outlines an ambitious concept of American education freed from bureaucratic control. Whether or not it earns a grant from NASDC, it deserves serious consideration by every parent, teacher, and policymaker in America. *Schools of the Marketplace* has the potential to re-create America's failing school system.

Steve Buckstein, President
Cascade Policy Institute
February 14, 1992

ACKNOWLEDGEMENTS

It is heartening to find a rich reservoir of people who are willing to assist in efforts to improve education. I would like to thank all those who helped in formulating the proposal, in reading and reacting to various drafts, and who offered ideas and resources—the deans, the superintendents, legislators, principles, consultants, parents, Educational Service District administrators and consultants, specialists, business leaders, directors, students, school board members, and professors who took the time to read and react to papers, prepare budgets and letters, and attend meetings.

Particular thanks to Lon Peters, Michael Rothschild, and John Jones for their very wise counsel and support. My very deep thanks to Richard Dennis for helping to make this proposal possible with his generous financial contribution to **Cascade Policy Institute**, and to Steve Buckstein and the **Cascade Policy Institute** for providing the guiding light and many hours of assistance and encouragement. I owe an especially deep debt of gratitude to my wife, Sandy Pellens for her remarkably creative gifts in education design, planning, and editing; to Tena Heeringa for her tireless research and computer work; and to Pat Jones because of her untiring spirit, very long and late hours planning and editing, and the educational model she exemplifies in her teaching which gives proof of what can be done for underserved students. Last, I want to thank my son, J Alex, for his support and willingness to give up his dad for so many weeks.

Richard Meinhard
February 14, 1992

Schools of the Marketplace: Executive Summary

In Portland, Oregon, there is a weekly open-air market called the Saturday Market. Saturday Market rents space to individual vendors who sell directly to the public. The fees charged by Saturday Market pay for joint marketing and such joint services as rest rooms and security. The market model has these noteworthy characteristics:

- Customers don't buy from the marketplace, but from individual vendors.
- The vendors own their businesses and the Market and so share in its profits and losses as well.
- The marketplace does not plan what goods or services are produced, the prices of those goods or services, or what combination of goods or services are purchased.
- The balances of supply and demand, profit and loss, and incentives for innovation operate on each vendor as well as on the marketplace as a whole.
- The marketplace does not specify the product but can place boundaries on vendors and products.
- Saturday Market has rapidly grown to become a highly valued part of the community featuring a remarkable diversity of handcrafted goods in an intimate setting.

Centralization and government control is an experiment which has failed.

The Saturday Market demonstrates the power of the American marketplace in freeing up individuals to create and respond to market needs of customers. What would a dynamic marketplace do for our ailing system of American education? The Cascade Policy Institute and the Institute for Developmental Sciences undertook to answer that question by designing schools based on an economic model to replace the current political model of public education.

Marketplace Schools—In *Marketplace Schools*, students are helped to focus on discipline-based developmental goals through the concept of human contracts—stating an intent and plan for accomplishing something, and then documenting delivery and performance. This free market system of contractual human obligations and rewards allows students to obtain personalized education services and frees teachers from bureaucratic rules and regulations in order to meet the individual needs of their students. Teachers in *Marketplace Schools* understand the structures of the disciplines as well as the psychology of student development. They are capable of working with and through learners' activities. Teachers help connect students to the real world and primary information sources through investigations, experiences, data bases, electronic learning technologies, community resources, and business internships. Here is the structure of *Marketplace Schools*:

- ***Students***—Any student can choose to receive state funds and enter *Marketplace Schools*. Financial resources are placed in student education accounts so they can choose the teachers, specialities, schools, and the duration of the relationship.

- ***Education plans and learning contracts***—By refining a long range development plan with their mentor teacher, students direct their learning to successfully enter into the three adult roles—civic, career, and personal. Students/parents choose a mentor teacher who stays with them to help develop a sense of purpose and carry out long range educational plans. Mentors also assist students in developing short-term learning contracts by locating educational resources and opportunities.

- ***Portfolios***—Public education should be an important contract between students and society. Students use contracts and public performance portfolios to organize their learning and to display the results of their in-depth investigations and projects. Student permanent portfolios may be public documents, available for inspection by citizens, researchers, higher education, and employers. Student portfolios document completion of contracts, the nature of students' learning experiences, and their final performance capabilities.

> *Public education should be an important contract between students and society.*

- ***Nature of learning experiences***—Students' learning activities are directed to accomplishing significant projects and investigations regarding the understanding of the fundamental structures of math, science, geography, history, English, and specialty areas students choose. Teachers help connect students to information sources from the real world through investigations, experiences, data bases, electronic learning technologies, community resources, and business internships.

> *A focus on the supply side of the market will permit teachers to emerge from the shadows of the bureaucracy and become professionals.*

- ***Professional Group Practice***—Teachers of *Marketplace Schools* form voluntary professional group practices (similar to those of architects, engineers, lawyers, and physicians) in order to offer educational services to students. These small group practices may locate in businesses, community sites, existing schools, or any neighborhood locations close to their clients. They offer educational experiences not bound by walls, clocks, or calendars.

- ***Involvement in learning***—Teachers work with and through learners' activities. To obtain high student involvement in learning, teachers base instructional methods on guiding learners through investigations and problem solving which allow students to develop the basic intellectual structures of understanding. Teachers accommodate a wide range of learning abilities and ages, and constantly seek to decontrol learners so as to nurture growing independence.

- ***Teacher autonomy***—Teachers determine what managerial and professional support services to jointly purchase to maximize the greatest responsiveness and resources in serving students. They operate autonomously in running a very open and public school (or small school within a school) to serve their clients--students and parents.

- ***Educational Development Corporation***—The EDC has two roles. It is both the development agency for the design and the support organization for *Marketplace School's* professional group practices. By brokering and developing its own services, the EDC serves seven functions: research and development, administrative services, teacher development, curriculum and instruction service, professional group practice development, franchise services, and system development.

Accountability—The goal of *Marketplace Schools* is not test scores; it is future success in life. The progress of students is measured by the development of intellectual structures rather than by meeting predetermined end points. In the *Marketplace School* benchmarks represent the degree and the quality of understanding rather than facts accrued. Consequently, learning contracts and activities are intimately and obsessively tied to the long range personalized education plan of each student. The same portfolio system is used for teachers whose professional portfolios are publicly available for parents, students, and others. Each professional group practice also documents their philosophical approaches, specialities, capabilities, the performance results of the school, and students' success after leaving.

> *The goal of* Marketplace Schools *is not test scores; it is future success in life... Learning contracts and activities are intimately and obsessively tied to the long range personalized education plan of each student.*

The system of public scrutiny used in the *Marketplace School* provides more accountability than other schools since (1) both the actual work plans and accomplishments of students and teachers are held up to public scrutiny, the public becomes an integral part of the everyday operations, and teacher researchers provide critiques; (2) both qualitative and quantitative evaluations monitor, not govern schooling, and (3) in an open environment, a teacher who does not offer or deliver a quality service does not attract clients.

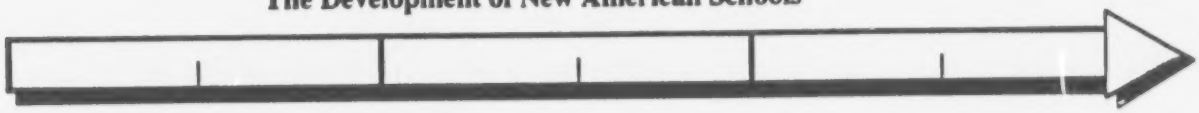
> *In our efforts to change education, how do we know we aren't just "talking the talk"?*

Theory—Just as the Saturday Market retains the rights to place boundaries on vendors and products, *Marketplace Schools* are bounded by clear economic, organizational, and human development principles. Therefore, *Marketplace Schools* are based on the most advanced, break-the-mold paradigms available.

In the research on the development of knowledge, Piaget's scientific findings have long shown that knowledge is not a state or a thing which is stored or transmitted. Knowledge is a mental activity organized by the learner which acts on reality and thereby also fits itself to it. Mental systems are living, self-organizing systems of interactions between the learner and the learner's cognitive environment.

In *Bionomics, Economy as Ecosystem*, Michael Rothschild explains the premise that economic and organizational development is not a product of rational planning nor a state of affairs. American economic growth occurs because it is free to self-organize, re-adjust, and create. Government planning does not provide the infinite wisdom necessary to construct, readjust, and fit the staggering complexity and infinite variety of relationships constituting an economic system. Development of organizations and economic systems evolve because they also are living, self-organizing systems of interchange.

The Development of New American Schools



Old Government Monopoly Mold	*Free Market Model*
• Controlling—Controls what's provided, when, where, and how it is provided, and the provider consumers must use	• Freeing—Frees up teachers to develop specialized services or seek new, underserved markets
• Political—Achieves agreements through group agreements and survey methods; individual must submit to group	• Non-political—Allows diversity; individuals free to dissent, experiment
• Inefficient—Expands services without regard to value; has no cost benefit mechanism for controlling costs or benefits	• Efficient—Teachers purchase only those support services they need in order to serve students
• Standardized—Insures services are standard, fair, and equitable to all; provides one best system which fits all	• Personalized—Fits specialized services to particular needs and long range development of students
• Coercive—Regulates by law; compliance through force	• Voluntary—Regulates by natural market balances
• Collectivized—Decides through use of boards, legislatures, and committees	• Individualized—Forms groups out of voluntary association and benefit of individuals
• Rhetoric—Shares limited information; forums for dissent closed or suppressed	• Research and Development—Seeks & invests in research & development of student growth; free disclosure & discussion
• Centralized—Invests authorizing at top; group; asks subordinates to implement	• Decentralized—Creation & initiation by individual; individual is responsible agent

These principles are taken from Michael Rothschild's break-the-mold model of self-organizing economic systems (*Bionomics: Economy as Ecosystem*, Holt, 1990) modern management theories, and Jean Piaget's profound explanations of how humans construct knowledge out of a self-regulated interaction between the learner and his cognitive environment. All are the most advanced, break-the-mold paradigms available. They provide a basis for the design of healthy, developing systems and a natural, developmental design process for a design team.

Design Process—The **New American Schools Development Corporation (NASDC)** stimulated the idea of forming a for-profit Educational Development Corporation to design

and develop *Schools of the Marketplace*. At the request of President Bush, NASDC was formed and funded by American business as an independent, non-profit corporation to fund the design of break-the-mold **New American Schools**. NASDC will support a number of design teams organized to create and test designs for schools that achieve national education goals and meet world class standards for all students and help these students leave school prepared for responsible citizenship, further learning, and productive employment; and assist communities across the nation to adopt and recreate these designs for their own purposes.

In response to NASDC's innovative call for proposals, the Cascade Policy Institute and the Institute for Developmental Sciences prepared a design proposal to request support for four functions:

- provide resources for the operation of the EDC and the design team
- establish three research and development lab sites which operate under subcontracts from the EDC to develop and test design ideas
- protect the independence of the lab schools and the EDC by insuring support and clients while issues of state funding are addressed
- remove some of the financial risk for initial participants

The EDC will issue performance contracts to three lab sites (the West Linn and LaGrande School Districts in Oregon and Vancouver School District in Washington) to help design and field test specific design features. Initially, twenty-five teachers serving approximately 500 k-12 students will be involved. Each site has a director who is the primary contracting agent and liaison with the design team.

These lab sites produce information the design team needs to write handbooks on *Student Development and Contract Learning in the Disciplines, The Professional Group Practice, The Educational Development Corporation, Teachers' Roles & Responsibilities,* and *The Replication of Marketplace Schools.* In its development, a market model starts small and grows only with success. Development funding provides money for the research, development, and disassociation of *Marketplace Schools* from the education bureaucracy.

Conclusion—We do not intend that our students learn *about* the disciplines and *about* technology. We intend that our students be the designers and constructors of these systems. America has always *set* world class standards, not *met* them.

> *America has always **set** world class standards, not **met** them.*

All education services and rewards must focus on understanding and promoting students' growth. From the earliest ages, students learn with their teachers how to plan and produce their own education. They formulate simple learning contracts for investigations into core and specialty subjects. As they progress, they grow and develop into constructive, moral, self-governing, and self-motivated adults representing the best of American values. They are the entrepreneurs, the inventors, the constructors, the writers, the creators setting new, world class standards of tomorrow.

Prologue: Breaking the Mold

East or West Berlin? It is Time to Offer the Choice

Using an analogy from the recent upheaval in Europe, we do not ask the East Berlin officials to improve the lives of their subjects. We design a West Berlin for all to see. If our new city offers a significantly better life to its residents, the Wall will collapse under the weight of a better idea.

It has been the American genius to demonstrate the remarkable creativity, productivity, and efficiency of the free marketplace of goods, services, and ideas. History is confirming that the source of human transcendence rests in opening up human freedoms, not in controlling, regulating, and standardizing them. American education is in desperate need of these human freedoms and creative forces.

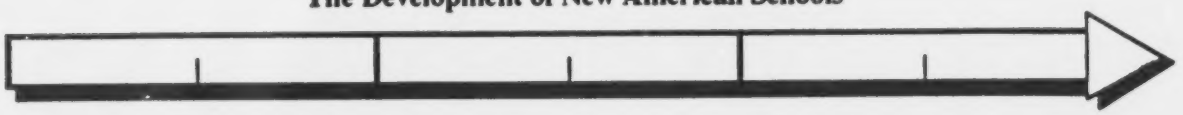
Research into the development of cognitive, instructional delivery, organizational development, economic, and governmental systems, shows that the fundamental direction of development of living systems is toward autonomous, 'free enterprise' forms. This is so because all living systems have built-in self-regulating processes which produce new system structures. To impose a plan on such living systems distorts their creative powers and destroys the diversity they require to thrive. Two advanced theories—the cognitive development theory of Jean Piaget, and the bionomics theory of Michael Rothschild—capture this idea of development out of self-organizing activity. Throughout our design we have represented this self-development of systems from a weak form to a stronger one with arrows which show the direction of development and progress.

Direction of Development and Progress

Centralized, Paternalistic Forms — Decentralized, Free Enterprise Forms

The direction of development of New American Schools would then look like the following:

The Development of New American Schools



Old Government Monopoly Mold	Free Market Model
• Controlling—Controls what's provided, when, where, and how it is provided, and the provider consumers must use	• Freeing—Frees up teachers to develop specialized services or seek new, underserved markets
• Political—Achieves agreements through group agreements and survey methods; individual must submit to group	• Non-political—Allows diversity; individuals free to dissent, experiment
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• Centralized—Invests authorizing at top; group; asks subordinates to implement	• Decentralized—Creation & initiation by individual; individual is responsible agent

We believe NASDC wants students to assume much more responsibility for their own learning. We believe teachers need much more control and ownership over their teaching enterprise. And we are certain that a system which frees student learning and teachers' instruction *cannot be produced by a government monopoly system of public education.*

The powers of self-regulation make organizations, mental operations, and organizations appear as intelligently creative rather than passively static. Human freedom is the grand essential which is necessary to unleash these powers. But the grand illusion of government monopoly schools and government control is that systems must have centralized, rational planning and control. That is simply not true. Centralized control inhibits and makes inefficient the creative initiatives inherent in the ownership of free human activity. Education in a free society should be the exemplar of free enterprise, not its socialist enemy. We propose to establish a free enterprise public school system of *Marketplace Schools* to unleash the creative and constructive capabilities of our students, our teachers, and our system.[1]

[1] The voluntary contract resulting from students choosing services offered by teachers provides a restructured relationship and makes them non-coercive. See William Glasser, *The Quality School: Managing Students Without Coercion*, (Harper Perennial, 1990) for an excellent discussion of this ideal of non-coercive, need satisfying, high quality schooling.

Part 1: What We Will Accomplish

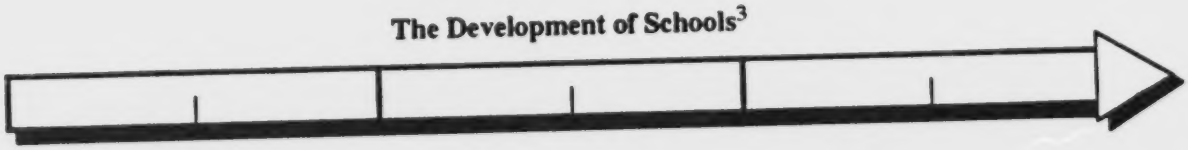
Student clusters encircle the room like satellites. One group of students is having an animated discussion about a short play they are writing about life in the 1920s and 1930s. Across the room another cluster of students is putting the final touches on a video documentary on the life of D. W. Griffith, who is buried a few miles away. They have divided up the research, the writing, and the actual production and seem proud, even a bit awed, of their work. Another group is finishing up a gigantic Hooverville house constructed from cardboard, not dissimilar to the rows of shacks that once stood on the banks of the nearby Ohio River during the Great Depression. As they work, they discuss the life of the homeless of yesterday and today...The teachers keep track of all this independent activity unobtrusively moving from group to group, observing and listening, answering questions, prodding, chiding. "I don't see myself as someone who should stand in the front of the classroom and give out information," the teacher explains. "That's something that students can and should get for themselves. I see myself as their academic coach. I (move) around making sure that everyone stays on target. They are the ones who do the teaching and learning. They teach themselves, and they teach each other. They learn a lot more than they would if I were just talking to them".

Edward B. Fiske, *Smart Schools, Smart Kids*[2]

WHAT OUR STUDENTS WILL ACCOMPLISH

As it is with bureaucracies, schooling in America turns in on itself to make its own requirements the ends of education. Schools teach for the test, and tests define school achievement. Schools teach schooling. They should instead teach intellectual growth.

The Development of Schools[3]



Old Mold	Break the Mold
• Growth standardized with uniform outcomes by all at grades 4,8,12	• Conditions established which allow & promote growth of students at all levels of development
• Many short term goals of mastery	• Long term goal of deep, discipline-based understanding
• External testing added on after learning	• Built in self-evaluation of learning projects and growth
• Disciplines isolated and sterilized	• Disciplines abstracted out of experiences with reality
• High school graduation rate (exit goal)	• Successful "ready for" entry into adult life
• Seat time for teacher controlled learning	• Brain time for student organized learning

[2] Edward B. Fiske, *Smart Schools, Smart Kids, Why Do Some Schools Work?*, (Simon & Schuster, 1991).

[3] Many writers have begun to recognize paradigms, or 'molds', and describe them with lists of their characteristics. We are suggesting much more. The facts of history and the developmental sciences show that paradigms have consistent features of an underlying common form, and these underlying forms—one-way, cooperative, and developmental forms—*have an order of development*. The arrow above the tables represents the stages of development of a particular system of thought or human organized activity.

Marketplace Schools make education and knowledge powerful tools for successful human activity rather than ends in themselves. *Marketplace Schools* focus student growth toward developing long range goals harnessing human intellectual capabilities to directly promote the ability to act and to succeed in three of life's fundamental roles: (1) family, (2) career adult roles, and (3) civic. *Marketplace Schools* are successful if students are successful. And that success is not only success in school but success in life.

Marketplace School students will develop and demonstrate two capabilities. They will construct a structural understanding of academic disciplines and they will develop skills which business and the world at large have come to expect of intelligent people. They will use their knowledge effectively to solve problems, work in groups and make judgments. In our *Marketplace School* the goal for each student is the healthy development of those deeper understandings of each of the academic disciplines and interpersonal relations which lead to successful participation in adult roles. Successful participation means success in three important adult roles:[4]

Interpersonal and Family:

√ *Engage in successful interpersonal relationships*

√ *Understand healthy human growth, value themselves, and don't resort to violence or abusive drugs.*

Career:

√ *Develop a specialty and commitment to its value and use*

√ *Successfully hold career positions and/or successfully participate in higher education*

Civic:

√ *Develop a commitment to life long learning to helping their community*

√ *Actively participate as a world citizen*

This fundamental change from short-term focus on simple learning to long-term focus on intellectual development requires qualitative changes in the student's role, teacher's role, and the organizational structure. Therefore, these role and organizational changes guide our design.

STUDENT DEVELOPMENT

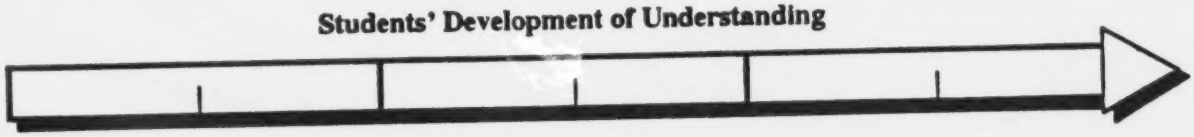
The young kindergarten child looks at two sticks placed side by side and sees that they are of equal lengths. We move one, and the child says, "that one is longer". He believes that because one appears to extend beyond the other, it is therefore longer.

The child is shown ten toy cows and three pigs and asked, "Are there more cows or more animals?" "More cows." "Why?" "Because there are ten cows and only three pigs."

[4] These goals closely match President Bush's America 2000 goals.

Endless scientific experiments repeatedly and consistently show that no act of knowledge is ever a passive reception; in every act of knowledge there is always an internal organization of thought-organizing mental activity shaping its reasoning, problem solving, and understanding.[5] These systems of internal organization do not come from experience or learning but develop from the effects of natural self-regulations inherent in all biological activity including human thought and knowledge. They produce stages in the specific development of each of the understandings students must put together,[6] and which, if understood, can be used to work with and measure student progress from work in portfolios.[7]

Students' Development of Understanding



Pre-Operational Understanding	Conceptual & Explanatory Understanding
• Sees world in terms of states & static relationships, centrates on end points or answers, poorly sees means	• Sees & understands transformations & how they fit together to produce a given state
• Unknowingly uses egocentric and illogical thought to distort reality and fit into self's perspective	• Uses rational concepts & reasoning to overcome & correct perceptions & appearances
• Uses oriented, one-way relationships in thought & activity	• Uses two-way reversible systems of thought & activity, or doubly reversible systems

Developing a New Role for Students[8]

We could simply *improve* student performance; that is, get them to do more of the kind of simple learning they are already doing. Or we could fundamentally alter the kind of intellectual growth we seek to promote. Rather than simply reviewing and learning material for performance on tests, our design for education seeks to address much deeper, longer range *qualitative changes* in students' understanding and capability to learn. To achieve such a deep and comprehensive change requires a fundamental redesign of the student's role. Here is how students will function in *Marketplace Schools:*

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[5] Reformers point out that schooling has trivialized the goals of education. Howard Gardner in *The Unschooled Mind* points out the disparity between teaching and understanding and sees "genuine understanding" as the fundamental goal of education. Or, see the Holmes Group call for focusing on students' understanding rather than learned responses in *Tomorrow's Schools: Principles for the Design of Professional Development Schools*. The focus of the developmental sciences is on the descriptions and explanation of the deeper organization of thought, the cognitive system, which form students' understanding. While performance tests measure learning and answers, developmental assessment measures the development of understanding. See Part 4 for more discussion of developmental theory.

[6] For an example of how developmental methods are used to assess students' understanding of specific understandings, see Richard Meinhard, "A Developmental Baseline Profile of 12 Key Elementary Science Concepts/Processes: Evaluation Report of the Developmental Assessment Project", (Portland, OR, Institute for Developmental Sciences, 1990).

[7] By portfolios we mean files which document work organized and produced by students, not worksheets. They require developmental methods for interpreting the level of understanding they represent.

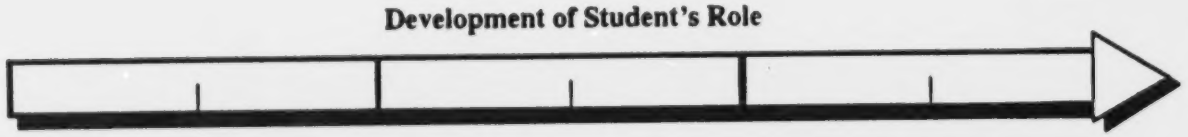
[8] Ted Sizer and the Coalition of Essential Schools are an excellent source for descriptions of the new role of the learner and the importance of deeper learning, i.e., "less is more."

• Students become powerful learners who exercise responsible ownership of the decisions regarding what they learn, when they learn, and with whom they learn.

Our vision for a world class learning environment alters the relationship of students to their own learning by reconstructing old notions about basic intellectual development. A high performance learning environment must focus on human intelligence as a powerful system of adaptation with the primary function of problem solving. Human intelligence did not evolve to simply store information but to vigorously confront, investigate, solve problems, and understand the world so that human activity could be planned, organized, described, and explained. Rather than requiring students to simply learn more standardized and pre-organized material to perform better on tests, students must be educated to delve into the actual construction of knowledge. They must be asked to directly investigate and develop an understanding of the world for themselves.

Adding or intensifying the coverage of material does not empower students to develop these deeper intellectual capabilities of academic thought, problem solving, and creative application. Thus, our vision shifts from a focus on rudimentary, short-range learning to the intricate, long-range cognitive development of students who take responsible ownership for their own learning. Students must assume the role of industrious researcher and constructor of knowledge.

Development of Student's Role



Externally Controlled Passive Learner	Self-Organizing Active Investigator
• Passive learning of what is presented & shallow performance	• Active investigation & construction of systems understanding
• Information memorized without real sense of purpose & short term learning for test	• Strange situations purposively confronted and organized into new understandings & long range investigations
• Pre-packaged, simplified knowledge learned from texts & teachers	• Complexities of reality confronted directly
• Function only under external control & rewards by teacher	• Function under internal motivation & rewards of relevance to own life, career, & personal development

Attempting to understand students' mental activity as opposed to overt behavioral activity raises the second issue—teachers' development.

TEACHER DEVELOPMENT

...Following that, the teacher had students create a box above their scale to label the concept, 'temperature'. "How do we talk about objects as they move in this direction along the scale? "Hotter", and then "colder". "How about the end points?" "Hottest". "Coldest".

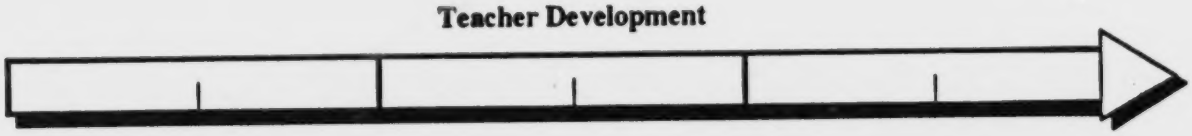
Then came more discussion and questions of what would have to happen to move an object along the scale, how one would know a change had taken place, how units could be created on the

scale, and what units had already been created. These created more investigations, and other sharing sessions.

Eventually, students had what the teacher called a 'learning format', which they repeated in investigating other measurable concepts...

Developmental psychology describes what fundamental changes in teachers' understanding and instruction are required to address intellectual development. The understanding that student growth is not a passive reception of canned knowledge but is in fact an active construction by the learner has been given much lip service. But what precisely are the fundamental changes in the primary functions of instruction? In *Marketplace Schools* there will be changes in (1) the curriculum specifying what is to be learned, (2) instructional method, (3) the learning activities of students, and (4) evaluation of students' growth.[9]

Teacher Development



Static, Topical Curriculum	Developmental Curriculum
• Describes topics, information,or materials to be covered	• Abstracts & describes the development of understanding of fundamental concepts
• Uses fragmented listings of content, skills, & knowledge	• Describes large, integrated wholes & systems of understanding & thought
• Uses static metaphors, 'cover material,' 'transmit', 'content', 'body of knowledge'	• Uses dynamic language of living systems, 'form of activity', 'self-regulation', 'compensations'
Reception Learning Activities	**Developmental Learning Activities**
• Pre-organized by teacher or text; time & place bound by teacher	• Organized by students; extended across time and place at control of students
• Discrete, well defined activity with clear closure	• Activity open with many options; leading to new problems & interests
• Learners' focus of attention focused on completed knowledge in text or teacher	• Learners' attention on real world & objects
Quantitative Tests	**Developmental Stage Methods of Evaluation**
• Quantitative tests of correct answers & retention reported in numeric scales	• Qualitative measures of the development of understanding reported in stage scales
• Focus on single answer responses to questions; data in gradebook	• Focus on display of thought & reasoning which produces the answers; data in portfolios
• Evaluation added on; the check for learning	• Evaluation integrated into learning as natural feedback mechanisms from group sharing, interactions/discussions, & critical analysis

[9] The qualitative changes in teachers' understanding and methods are outlined in Richard Meinhard's "Concept/Process-Based Science: Science Curriculum Concept Paper #4," (Oregon Department of Education, 1990) and in Richard Meinhard's "Contributions of Piaget to Science Education: Science Curriculum Concept Paper #2," (Oregon Department of Education, 1989).

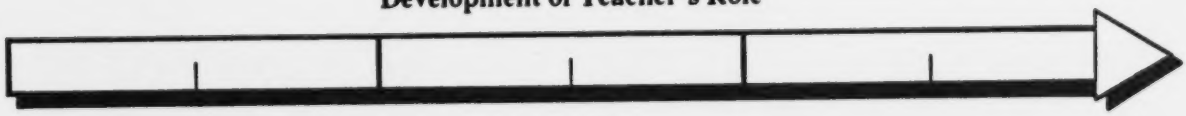
Developing a New Role for Teachers

The public school transmission-of-knowledge approach to teaching clearly violates well established scientific principles from developmental psychology.[10] Developmental research clearly reveals that the source of knowledge for students lies in students' activity, not in the transmission of fully formed knowledge.

The activities students engage in must place the student in direct interaction with the world. A cognitive system is a developing interaction between the understanding of the student and his/her experience with the world, neither of which come from direct transmissions from language, the teacher, or objects. While the teacher can help the student develop an understanding and help the student experience an object of study, teachers cannot act as a substitute. If we are to heed the developmental principles of student growth, student activities must be released from a focus on the teacher and from teacher control. They must be redirected to the world and the objects students are attempting to understand. The role of teachers must necessarily change to support the new student role.

• For students to develop advanced intellectual capabilities, teachers must change from transmission methods of teacher controlled learning to developmental methods.

Development of Teacher's Role



Transmission Methods	Developmental Methods
• Carefully present information to be covered	• Open up the world to students & pose knowledge as a problem of investigating the world & organizing learning activities
• Focus on short term goals of information or procedures to be learned	• Help students to relate & group understandings into larger systems of explanation and understanding
• Isolate each skill or content to be learned	• Give ownership of learning & responsibility to students. Pose the organization of learning activity itself as a problem the learner must solve
• Teacher ownership & responsibility for learning. Teacher controls learning activity	• Help students find & develop their own strengths & make unique contributions
• Treat all students alike in what and when they learn; make students do their own work, work in isolation, & compete in zero sum power relationships. Make diversity abnormal	• Help students to support & cooperatively work with others & use diversity as a resource operating within our American values

10 "Teacher talk violates everything we know about how students learn and the diversity of learning styles," says Edward B. Fiske in *Smart Schools, Smart Kids*, (Simon & Schuster, 1991), p. 64. Part 4 emphasizes the importance of the activity of the student. Working with the development of students' understanding directly counters pre-planned, lockstep curriculum and teaching which predominates in public schools.

For high performance learning, teachers must make a profound shift. They must redesign their instructional method and reconstruct their understanding of student growth. Rather than asking teachers to focus on carefully presenting material to be learned by all students, our vision asks teachers to educate students to take charge of investigating the world. Teachers must embrace and use individual differences not by designing individual lesson plans which patronize learners but by working with students to formulate educational, personal, and career development plans.

Public school teaching resists serving the individual student. *Why doesn't the public school system focus on understanding and promoting student development?* A look into organization theory suggests several reasons for ignoring the student, and it raises the third issue of organizational development.

ORGANIZATIONAL DEVELOPMENT

> *Bionomics* holds that, like an ecosystem, a market economy is a natural and spontaneous evolutionary process. Neither of these exceedingly complex systems was planned. Neither requires central management. In fact, because both systems are so complex and ever-changing, attempts to consciously manipulate either one tend to have highly destructive, though unintended, consequences.
>
> Michael Rothschild, *Bionomics*[11]

Developmental theory explains how students and teachers grow and develop. *Bionomics* explains organizational development—how organizations and economic systems are living, self-organizing systems.[12] The bionomics' explanation of living systems provides another basis for knowing that human systems of all kinds design themselves. The market economy was not planned. It is the way human society organizes itself for survival in a world of limited resources.

Developing a New Role for the Organization

The bureaucratic structure of the education system shapes all relationships. For teachers to develop into their new role, *Marketplace Schools* change the organization's role.

• An educational delivery system must liberate and empower its participants so they may focus on market driven quality and personalized long range educational development for each student.

By establishing a fundamental, interactive relationship between teachers and students, the relationship of administrators changes from that of an authority and supervisor over teachers and students, in the implementation of a top-down policy, to that of a support staffer responding and serving teachers' needs at teachers' requests.

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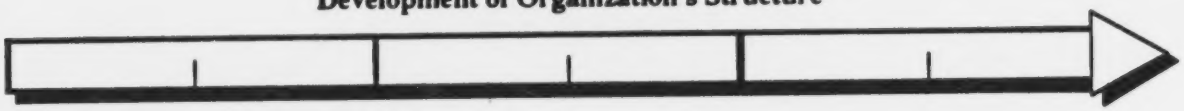
[11] Michael Rothschild, *Bionomics: Economy as Ecosystem*, (Henry Holt, 1990).

[12] Both Rothschild and Piaget arrive at three fundamental ideas which underlie and explain the organization of knowledge and economies—they are both *living* systems, they both learn and create new forms, and they are self-regulating in their interchanges with their environments. See part 4.

Development of Organization's Structure



Government Bureaucratic Form	Client Driven Professional Form
• Top down, hierarchical management structure	• Bottom up client driven
• Flow of information and authority from top to bottom	• Interactive information exchange
• Teachers reactive to rules, standards, regulations, supervision	• Teachers respond & adapt to market needs of students
• Programs decided centrally, implemented by subordinates	• Decentralization, specialization, & cooperation by participants
• Controlled slowly by rules & regulations	• Regulated by dynamic, self-organizing processes of supply & demand
• Committee & political methods of change	• Change generated by research into problems & development of new programs

Part 2: Our Basic Concept

THE MARKETPLACE

In Portland, Oregon, there is a weekly open-air market called the Saturday Market. Saturday Market itself rents space to individual vendors who sell directly to the public. The fees charged by Saturday Market pay for joint marketing and such joint services such as rest rooms and security. The market model has these noteworthy characteristics:

- Customers don't buy from the marketplace, but from individual vendors.
- The vendors own their businesses and the Market and thus share in its profits and losses as well.
- The marketplace does not plan what goods or services are produced, the prices of those goods or services, or what combination of goods or services are purchased.
- The balances of supply and demand, profit and loss, and incentives for innovation operate on each vendor as well as on the marketplace as a whole.
- The marketplace does not specify the product but can place boundaries on vendors and products.

Saturday Market has rapidly grown to become a highly valued part of the community featuring a remarkable diversity of handcrafted goods in an intimate setting.

MARKETPLACE SCHOOLS

A marketplace is a richly creative and highly diverse place. Its efficiencies and intricate methods of production don't show in the galleries of finished products offered to consumers. What kind of constructive activity lies behind the finished products in the workshops, design laboratories, construction sites, working offices, work spaces which produce the wares of a market? If we are to imagine *Marketplace Schools*, we must imagine that diverse, productive activity.

Marketplace Schools are not places to buy finished ideas. They are sites of elaborate constructive activities of students as they investigate and build understandings. They are sites for small groups of professional teachers dedicated to providing personalized, market driven quality services to students.

Physical Space—The physical space of *Marketplace Schools* corresponds to the rich, in-depth projects organized by students with the help of teachers. Space is organized around projects, investigations, and student activity. It is fluid and changing as activities grow and develop. Rather than general purpose, one-size-fits-all space, *Marketplace Schools* reflects particular specializations and capabilities of students and teachers. Space is not the property of teachers or organized to reflect teachers. One space with large tables and presentation facilities serves the need to gather for group planning, review of work in progress, analyzing problems, making presentations, and critiques of completed work. Because work is sometimes private and individual, each student can claim a space in the *Marketplace School* in which to establish an office, a worktable, a reading and writing desk, or whatever design fits individual needs. Each

teacher also maintains a private, well equipped office for personal use and meeting with students and parents. Throughout, computers are decentralized tools for gathering and organizing data, designing projects, performing operations on data, presenting information, communicating, and writing.

Information Flow—Student and teacher interactions serve as the circulatory system for the vital information exchange which is the lifeblood of intellectual growth in *Marketplace Schools*. Students make heavy use of information systems and computers to tap into electronic data sources, networks, data bases, and bulletin boards. There is an information center which displays printouts from the computerized information system and bulletin boards. It comes alive with "want ads": opportunities and information regarding interchanges and internships among teachers, students, alumni, community and business contacts, groups and meetings. Some ads are projects about to start, off-site learning experiences, and educational services and resources.

Public Sharing of Work—Diverse people gathered to learn to work together reflect a great respect for each task and each person involved. The value of the products and completed work coming out of *Marketplace Schools* is demonstrated by its public display in a gallery area. Here, learning products are held up for scrutiny, shared, and displayed in a showroom of intellectual accomplishment. The names of graduates and their current situation are displayed for all to see. These are alumni who provide a rich source of contacts in the community, who return to the school with their own contributions, and who help to establish a learning community within the community.

THE ORGANIZATION OF *MARKETPLACE SCHOOLS*

The Concept of Educational Development Corporations

The **Educational Development Corporation** (EDC) is the linchpin in the design of *Marketplace Schools*. While we will use the term EDC to refer specifically to our development corporation, all schools based on a marketplace design contract with the EDC of their choice. Competition among EDCs is a healthy aspect of *Marketplace Schools*.

The Educational Development Corporation (EDC) receives its funding by selling support services to teachers, groups of teachers we designate **professional group practices**, and schools. It is the primary tool for developing a new education ecosystem. It provides five kinds of services:

(1) Administrative and Support Services

> The EDCs offer basic operating, administrative, and financial accounting services to serve *Marketplace Schools*, other schools, or teachers who choose to buy the services. Since teachers decide what services to purchase, they become "clients" using services offered by the EDCs.

(2) Teacher Development

> EDCs buy and sell teacher development services including **teacher education** for those entering the profession. It locates master teachers who wish to provide (via contract) clinical training for students in a teacher education program. *Teaching Schools* are *Marketplace Schools* having master teachers providing site-based teacher education

services such as internships, clinical residencies, specific instructional methods, or traditional practice teaching for entry to the profession.

The EDC buys and sells **continuing teacher education** services by responding to teachers' needs and locating and sponsoring coursework offered by on-site teachers, teacher researchers, or professional group practice sites who operate *Continuing Education Centers.*

The EDC also provides **instructional services** to practicing teachers who want on-site assistance or internship opportunities for developing advanced instructional (or even basic) specialties.

(3) Research and Development

The EDC sponsors development projects for the (a) design and dissemination of instructional programs for *Marketplace Schools* and (b) organizational development by contracting with teacher researchers. Research and development services are contracted from practicing professional teachers in professional group practices who operate *Research and Development Lab Schools.*

(4) Public Education Information System

EDCs provide a system of public information to teachers, schools, professional group practices and others who subscribe for only those services needed. The system itself provides four services. The first is public **portfolio information** on teachers, professional group practices, and EDCs for use by parents in locating and choosing service providers, and for public accountability. The second is **education information** for teachers and students regarding curriculum, instruction, learning resources, and research information. A third service is **marketing information** about education opportunities offered by various sites. And, finally, the system provides a **networking service** for teacher and student exchanges.

(5) Development Services

EDCs offer development support and services during the phase-in process of **new professional teachers** to insure the success of beginning independent teachers. New teachers can start small with a few students and careful instructional assistance. EDCs offer financial, consulting, and development services to assist teachers to design and establish **new professional group practices**. Services also include locating buildings and conducting market research.

EDCs will offer assistance in other geographical regions without EDCs to assist in the development of **new EDCs.** Assistance involves development funding, establishing organizational structure and technology for the public education information system and the teacher network.

Professional Group Practice

In order to offer comprehensive educational services to students, teachers who choose to join *Marketplace Schools* form voluntary associations, professional group practices (similar to those of architects, engineers, lawyers, and physicians). These small group practices locate in

businesses, community sites, existing schools, or any neighborhood location close to their clients (the students), and offer educational experiences not bound by walls, clocks, or calendars.[13]

Professional group practices empower teachers to establish specialities and cooperate with other teachers to offer programs under the identity of their professional group practice. The reputation of a professional group practice becomes an important asset to member teachers. Such a group practice may take in junior members and organize themselves to their benefit. Each professional group practice also has a portfolio requirement to the public education information system.

Teachers decide their form of organization, charters and governance. They determine what administrative and professional support services to jointly purchase, what remains under the control of individual teachers, and what ownership rights will be established.

Teachers display their specialities, performance and results in a public teaching portfolio as part of the public education information system and marketing services operated by an Educational Development Corporation. All teachers must belong to a public education information system in order to receive public education funds from students. As public information, these portfolios assist parents and students in selecting teachers and also provide abundant data for researchers and public policy analysts. Independent teachers will provide all administrative and financial services for themselves, or contract with a professional group practice or an EDC to provide those services.

Personalized Education Plans

The personalized education plan for each student establishes the primary education contract between the *Marketplace School* and the student. It serves as a cumulative record of student performance and as a personalized curriculum plan leading to the student's adult goals. It is reviewed and refined with the mentor teacher chosen by the student and his/her parents. The mentor teacher also assists the student and parents with finding and securing teachers and educational services they need. The long range personalized education plan promotes students' sense of purpose and responsibility for their own education, (hence..."ownership") and allows a single teacher to assume long range responsibility and authority for assisting specific students in their growth.[14]

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[13] James Conant articulated the notion of the large, "comprehensive high schools" in an influential 1959 report, *The American School Today*. However, Thomas Toch in *In the Name of Excellence*, (Oxford University Press, 1991) says, "But by the measure of the alienation and apathy that so pervade the nation's large, comprehensive secondary schools today, Conant was wrong" (p. 264). The importance of smallness and personal contact is being recognized through designs such as schools within a school (pp. 263-271).

[14] According to James Comer the problem of discontinuity is particularly serious for minority youngsters, especially African Americans. The Comer model is based on the notion that human beings thrive in supportive environments. R.G. Bridge and J. Blackman's' study of the Alum Rock, California voucher experiment of 1972 to 1977, *A study of Alternatives in American Education, Volume IV: Family Choice in Schooling*, (Santa Monica, CA: The Rand Corporation, 1978), Report No. R-2170/4-NIE showed poor families had less awareness of their choices, fewer sources of information, less accurate information, and used personal contacts rather than printed materials more than did higher SES (socio-economic status) parents. Other researchers have shown low SES families have a presumption of "low fate control" (Coleman's label for powerlessness) and its effects on valuing educational opportunities. Melvin Seeman in addressing the effects of alienation in "Alienation and Knowledge-Seeking: A Note on Attitudes and Action," *Social Problems*, 20, no. 1 (1972): 3-17, concludes that research demonstrates the correlation between powerlessness and knowledge holds true for school achievement, healthy, political knowledge and other actions as well. Alienation is a key mediating variable in determining whether people feel helpless and give up.

Contracts are representations of basic human relationships of performance and exchange. In *Marketplace Schools*, all parties to a contract personally commit to in-depth involvement and success. Learning contracts, negotiated by a student or a group of students, allow teachers to respond to a wide range of individual diversity. They promote integrity in relationships and ownership of learning by developing students' capabilities to plan, carry out and document performance. They form the primary means of planning educational services. Student contracts for learning activities focus on accomplishing significant projects and investigations directed toward an understanding of the fundamental structures of math, science, geography, history, English, and other student-chosen areas. One of our lab schools already incorporates learning contracts as a tool for planning and coordinating high success learning activities.

In *Marketplace Schools*, students as well as teachers document learning contracts and demonstrate performance of completed work in portfolios. For the students, short term portfolios are private and used to organize and document daily learning between teacher and student. Only completion of the best work of students and their long range education plan goes into a permanent portfolio. Permanent portfolios are made public, available for inspection by citizens, researchers, higher education, or prospective employers. As part of completion of their permanent portfolio, students publicly present their completed work in all disciplines and specialty areas to document their best performance capabilities.

THE FINANCE AND GOVERNANCE OF *MARKETPLACE SCHOOLS*

Currently, by legal structure of the education bureaucracy, teachers cannot serve and respond to the needs of their students as clients. Re-orienting the teacher's relationship away from the bureaucracy (figure 4) to serving students, as in figure 5, requires a new education system made up of non-coercive relationships. This is achieved by developing a new, non-bureaucratic system of schooling parallel to the current monopoly system.

The concept of *Marketplace Schools* envisions nothing short of the design and development of a completely new education system where students have access to highly specialized and personalized educational services from the teachers of their choice. Our design process develops a new conception of the teacher's role—from that of worker and bureaucrat supervised and directed by rules, regulations, standards, committees, and tests from above, to an autonomous professional who is subordinate only to serving the education needs of students, their clients.[15]

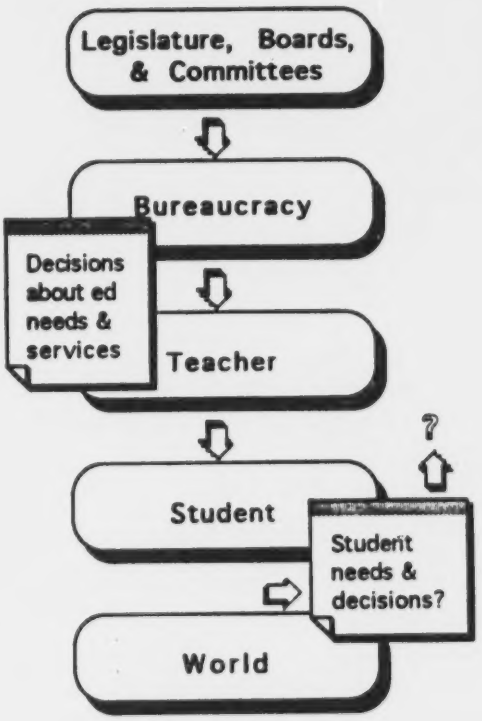

Figure 4: Top down bureaucratic system of management

[15] Chester Finn points out that 'choice' is one of our "band-aids for battle wounds" of public schools. That is probably true if 'choice' refers only to freeing the demand side of the teacher/student relationship. It may do little good to free up the consumer side if the government maintains monopoly control over teachers and the services provided. Finn, in his excellent, penetrating book, *We Must Take Charge, Our Schools and Our Future*, (Free Press, 1991) lays out problem after problem caused by public monopoly school systems—"paralyzed by design" "without accountability", and embarked on a "journey without a destination," yet he seems strangely resistant to tackling monopoly ownership itself, and his solutions tend to reduce to rhetoric—"we must take charge." The real choice, point out David T. Kearns and Denis P. Doyle, is whether the purpose of education is to serve the state or the students and parents. If education serves the state then it must be run by political processes and it must be all things to all people (*Winning the Brain Race: A Bold Plan to Make Our Schools Competitive*, San Francisco: ICS,1991, p. 29). For us in the design process, the choice is whether to have teachers serve a bureaucracy (albeit "democratically controlled" at some level) or serve students. We chose the students. John E. Chubb and Terry M. Moe in *Politics, Markets, and America's Schools* (Washington D.C.: The Brookings Institution, 1990) give empirical evidence that an economic model for education is more responsive and productive than a political model.

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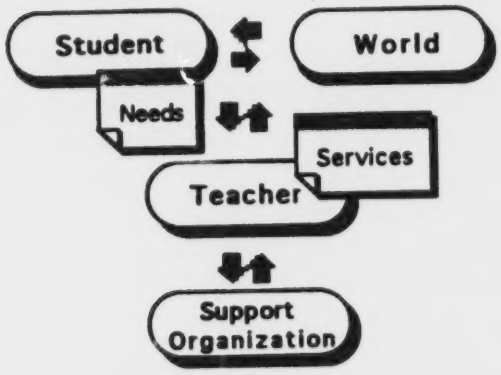

Figure 5: Healthy, interactive and responsive system

In *Marketplace Schools* the education system places decision making authority and control of resources with teachers. The system assumes a supporting function at the service of teachers for those teachers who are willing and capable of taking responsible ownership of their new professional role.

State, local and federal funds go to a student education account which the student can draw upon to purchase education services from teachers. Funds may be drawn to pay for any services provided by public schools. The state reviews all payments, and payments may be made subject to public scrutiny by recording them in the education information system.[16]

How We Will Design *Marketplace Schools*

How is a free market system designed? How do we design a system of *Marketplace Schools* without using the very model from which we're trying to free ourselves, that of centralized planning? We believe firmly in the creative, self-regulating powers of human systems free to carry out exchanges among themselves. We propose to immediately begin to establish, to the extent practically possible, a public education ecosystem of deregulated schools. Who tells entrepreneurs what to design, what to produce, who should offer products at the Saturday Market? The answer is no one; so how do we design schools where no one has design power over them?

- Establish the Educational Development Corporation as both an object of our design effort and developmental agent for *Marketplace Schools*
- Provide school site laboratories to develop and test smaller segments of the design through use of subcontracts
- Initially protect the design team and the test sites from regulatory control through adequate financial support
- Facilitate site-based design teams of practicing professionals in proven leadership schools eager to freely participate

We will emerge from the first year with the beginnings of a new education ecosystem developing (a) *Marketplace Schools*, (b) practicing teachers with some initial experience as teacher researchers and developers, and (c) our primary development agent, the Education Development Corporation.

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16 For a discussion of various funding arrangements, see Joseph Bast and Robert Wittmann, "Educational Choice Design Guidelines," Heartland Policy Study no. 39, (Heartland Institute, May, 1991).

Our EDC as the NASDC Contractor

Initially, the Education Development Corporation (EDC) will receive the NASDC contract to design all aspects of the *Marketplace Schools*. The EDC operation and office includes an executive director coordinating and leading the design effort. The EDC contracts with each of the executive design team members. It also provides for consultant contracts in areas such as governance, finances, state economics, information technology, pedagogy, research, evaluation, and technical writing. We intend to include the widest possible participation and critique through a system of *Consultants* (under specific design contracts) and critical friends (advisory supporters), and we shall make extraordinary effort to secure the full participation of parents and students since they remain without powerful organizations in the current education system.

Since it is envisioned as a support organization for the self-development of *Marketplace Schools*, the EDC will immediately issue subcontracts to our three lab schools to begin the development process. Performance contracts will go to the West Linn and LaGrande school districts in Oregon and the Vancouver School District in Washington to help design and field test specific design features. They will be funded to study the process of freeing a school from bureaucratic control and to implement possible solutions for design elements. Initially, twenty-five teachers serving approximately 500 k-12 students will be involved. Each site will have a site director acting as the primary contracting agent and liaison with the design team. The EDC lab contract will fund the site, the individual teacher, and pupil costs. These sites will produce information the design team needs to write handbooks describing all aspects of (1) the professional group practice, (2) the student (including the contract learning system in the disciplines) and the portfolio system, (3) the teacher, (4) the EDC, and the (5) development and growth of new *Marketplace Schools*.[17]

During the design in Phase I, the EDC serves three functions: (1) planning and coordination of the design process, (2) production of all materials required by NASDC, and (3) oversight of financial and contract management. However, as an on-going integral part of a new education ecosystem of *Marketplace Schools*, the EDC concept itself must be studied, developed, and described as part of the design to NASDC.

Our overall first year goal is to incorporate a research and development process in public schools in order to design and develop *Marketplace Schools*. We intend to study both the essentials in establishing new *Marketplace Schools* and a strategy to cut an existing school away from public bureaucracy. The whole design process is broken down and managed through subcontracts so that NASDC and the EDC have maximum flexibility and accountability.

[17] See Part 5 for a table outlining the contents of the five handbooks.

Part 3: The Design Team and Its Qualifications

We will not restrict the design effort to a single agency but will use a sub-contract system to obtain the widest possible, cost efficient involvement of our leadership in the Northwest. The design team includes those who have expressed their support for the exploration of the idea of *Marketplace Schools.*

Educational Development Corporation

Three design team members have primary responsibility for the contract performance. Richard Meinhard will devote full time, and Patricia Jones and Sandra Pellens 60% time.

Richard Meinhard, Ph.D: Director, Institute for Developmental Sciences. Dr. Meinhard has taught at the elementary, junior high, and college level. He will serve as the executive director of the design project and coordinate all research conducted at the lab sites of the *Marketplace Schools.*

Patricia Jones, M.S.: President of Institute for Developmental Sciences. Ms. Jones teaches full-time in an alternative high school in Vancouver, WA. She will be a primary designer and participate in the research at the Vancouver, WA, lab site.

Sandra Pellens, M.S.: Consultant, Curriculum and Instruction, Clackamas County Education Service District. Ms. Pellens teaches courses and help teachers at all grade levels and in all subject areas throughout the county. She will serve as a primary designer who coordinates and compiles the research products from the lab sites of the *Marketplace Schools.*

Economics and Public Policy:

Key to the design effort are fundamentally new conceptions of education economics and careful public policy analysis.

Michael Rothschild: Author, *Bionomics: Economy as Ecosystem.* Business consultant specializing in competitive planning for companies experiencing rapid technological change. Brings expertise on how market structures can be used to improve education.

Martin Buchanan: Technical writer and software engineer for major companies. Former chair, TEACH-OREGON. Author of Oregon's 1990 Educational Choice Initiative. Brings overall system expertise, writing and conceptual ability, and knowledge of educational politics.

Steve Buckstein, M.B.A.: President, Cascade Policy Institute. Coordinator of Oregon's 1990 Educational Choice Initiative campaign. Brings expertise dealing with public policy issues.

Tracie Sharp: Program Director, Cascade Policy Institute. Formerly Project Director, Washington Institute for Policy Studies in Seattle. Brings five years' experience in public policy analysis, organization, and implementation.

School Administrators:

At the heart of the site-based design process are the lab schools:

Barbara V. Fabert, Ed.D.: Director, Ackerman Lab School, Eastern Oregon State College. Brings national experience in pre-service teacher education and research in system-wide educational excellence.

Steven Friebel: Principal, Pan Terra High School, Vancouver, WA. Brings experience in adult education and alternative school leadership in California and Washington.

Jane Stickney: Principal, West Linn, OR. Has developed a leading elementary school. Expertise in school start-up, staffing, and leadership theory.

Other Team Members:

Other design team members bring specialties from business and education, career planning, curriculum, instruction, support services, student and parent relationship, public school superintendency, Educational Service District superintendency, teacher education, finances, and business operations. They were listed in the proposal to NASDC to show how a contract system can address a wide variety of particular design problems and draw in participation by powerful specialists and those in leadership positions without requiring premature endorsement of an untested design.

Part 4: The Theoretical Bases

> Bad Theory is still better than no theory at all and, for the most part, critics of orthodoxy have had no alternative construction to offer. The moral of the story is simply this: it takes a new theory, and not just the destructive exposure of assumptions or the collections of new facts, to beat an old theory.
>
> Michael Rothschild, "Time to Shift the Paradigm"

SCIENCE OF EDUCATION

Many exemplary reforms are already at work improving selected aspects of existing schools--innovations in curriculum, teacher training, calendar modifications, "one-stop" centers for social services, and accountability mechanisms. But, something about the current theory or mold has greatly limited even our best and most massive reform efforts. It limits state efforts to improve education, it drains resources, it stymies even its best and brightest administrators and teachers. Worst of all it constrains students, keeping them from the remarkable intellectual development of which they are all capable. Before the "how" question, therefore, must come the "why" question. Designs for "new" schools should be founded on causal theories which explain the mechanism underlying the reformation. *Marketplace Schools* primarily rest on the theoretical work of two scientists: Jean Piaget and Michael Rothschild.

While many researchers (e.g., Kohlberg, Hunt, and Lovinger) have worked to understand the nature of development in intellectual growth, it is Piaget who contributed a science of knowledge which studies and explains the source of knowledge. Piaget's genetic epistemology explains how mechanisms of development in biological activity elaborate activity until it reaches the level of scientific thought. Human intelligence is a continuation of biological adaptation. Human activity makes contact with, and fits itself to, reality such that it comes to reflect reality in the precise manner of objective knowledge.[18]

In research on the development of knowledge, Piaget's scientific findings show that knowledge is not a state or a thing which is stored or transmitted. Knowledge is mental activity which actively organizes and acts on reality and thereby also fits itself to it. Mental activity arises out of the continuation of behavioral activity by reconstruction and conceptualization in systems of mental activities.[19]

The implication of Piaget's' research for education is that knowledge cannot be pre-organized and transmitted to students. Rather, knowledge must be developed through students' activity because teachers cannot transmit to students the coordination of mental activities into concepts nor do students have innate capabilities which allow immediate comprehension of

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[18] Jean Piaget, *The Psychology of Intelligence*, (Totowa, NJ: Littlefield, Adams & Co., 1960), pp. 14-17; *Genetic Epistemology*, (Columbia University Press, 1970), p. 12; *Principles of Genetic Epistemology*, (Basic Books), 1972, pp. 19-20, 52-62. Supposedly the work of Piaget is outdated. However, education has never come to grips with either a science of education or with Piaget. It still remains the most advanced work available. See Richard Meinhard, "The Contribution of Piaget to Science Education: Science Curriculum Concept Paper #2," (Oregon Department of Education, 1989).

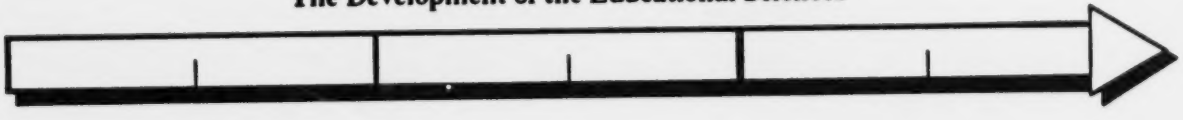
[19] See Jean Piaget, *The Child and Reality: Problems of Genetic Psychology*, (Grossman, 1973), pp. 49-61; and *Biology and Knowledge* University of Chicago Press, 1971), pp. 1-7.

meaning. Teachers' verbal information can only trigger mental activity at the levels of thought which students have themselves developed.[20]

The fundamental switch from traditional ideas of knowledge to knowledge as systems of mental activity changes the nature of the problems, roles, and needs of teachers. This shift from directly presenting and teaching completed knowledge to working with students' active involvement in learning and construction of knowledge out of their activities, fundamentally changes several functions of teaching.[21]

The source of knowledge for students does not fundamentally lie with the teacher, direct experience with objects, language, demonstrations, or visuals; the source of knowledge lies within student's organization of activity. To know does not mean to receive impressions and data from which to generalize. To know means to mentally act on the object and thereby to reconstruct it in thought.[22]

The Development of the Educational Sciences



Old Mold	New Model
• Students & organizations are passive products, treatment effects, outcomes, or states: provide instruction & determine effects, teaching as independent variable & student as dependent variable	• Students & organizations are dynamic, living systems whose outcomes are increasing capabilities of self-regulation and self-elaboration
• Uses mechanical metaphors for external controlling agent who 'causes' change in student or organization: transmission of knowledge, jump-start the economy, reform the system	• Uses biological metaphor for self-constructive powers: feed, support, free the self-constructive activities of living system
• Empiricism, behaviorism, classical economics, factory model management theory	• Developmentalism, bionomics, cybernetics, self-organizing systems theory

The developmental sciences and in particular, Piagetian developmental psychology and genetic epistemology, are reflexive in that they not only produce scientific knowledge about human and organizational growth, they turn back on themselves to explain the self-development of their own methods and understanding because they are about studying and explaining how scientific knowledge grows and develops. Correspondingly, we have used this idea as the theoretic basis for our design by making *Marketplace Schools* self-developing by building in a research and development function which not only addresses student development but turns back on participants to study teacher and organizational development.

Developmental research tells us that the source of knowledge for students lies in students' *activity*, not in the *transmission* of fully formed knowledge from outside sources. The findings from developmental psychology provide an urgent call to free teachers from lock step curriculum and highly controlled, textbook-bound learning so that teachers can explore, experiment, and

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[20] Piaget, *Child and Reality.*, p. 119.

[21] Jean Piaget, *To Understand is to Invent: The Future of Education*, (Viking, 1973) pp. 1-37.

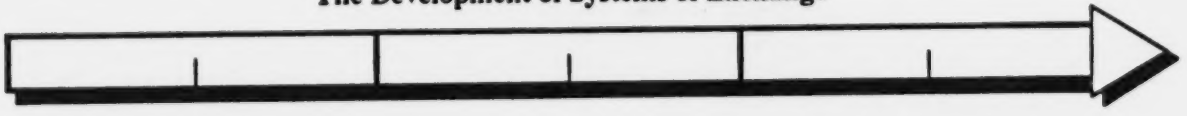
[22] Jean Piaget, *Science of Education and the Psychology of the Child*, (Grossman, 1970). pp. 10-20.

construct educational methods sensitive to promoting student growth. These same general findings regarding the importance of freedom, self-responsibility, and development hold true in organizational research as bionomics so clearly reveals.

ORGANIZATIONAL THEORY

In *Bionomics: Economy as Ecosystem*, Michael Rothschild expounds on the premise that economic and organizational development is not a product of rational planning nor a state of affairs. The remarkable fecundity and creativity of American capitalism is not due to careful government controls, adjustments and fine tuning, or "kickstarts to get it going." American economic growth occurs because it is free to self-organize, re-adjust, and create. Government planning does not provide the infinite wisdom necessary to construct, readjust, and fit the staggering complexity and infinite variety of relationships constituting an economic system. Development of organizations and economic systems evolve because they are living, self-organizing organisms. It is the "invisible hand" of the free market as a living organism. True, this organism has no material body or physical structure, but it is a living, sociological organism nonetheless. **And it is as difficult for central planners to give up the illusion of control over the economy as it is for teachers to give up the illusion of control over learning.**

The Development of Systems of Exchange

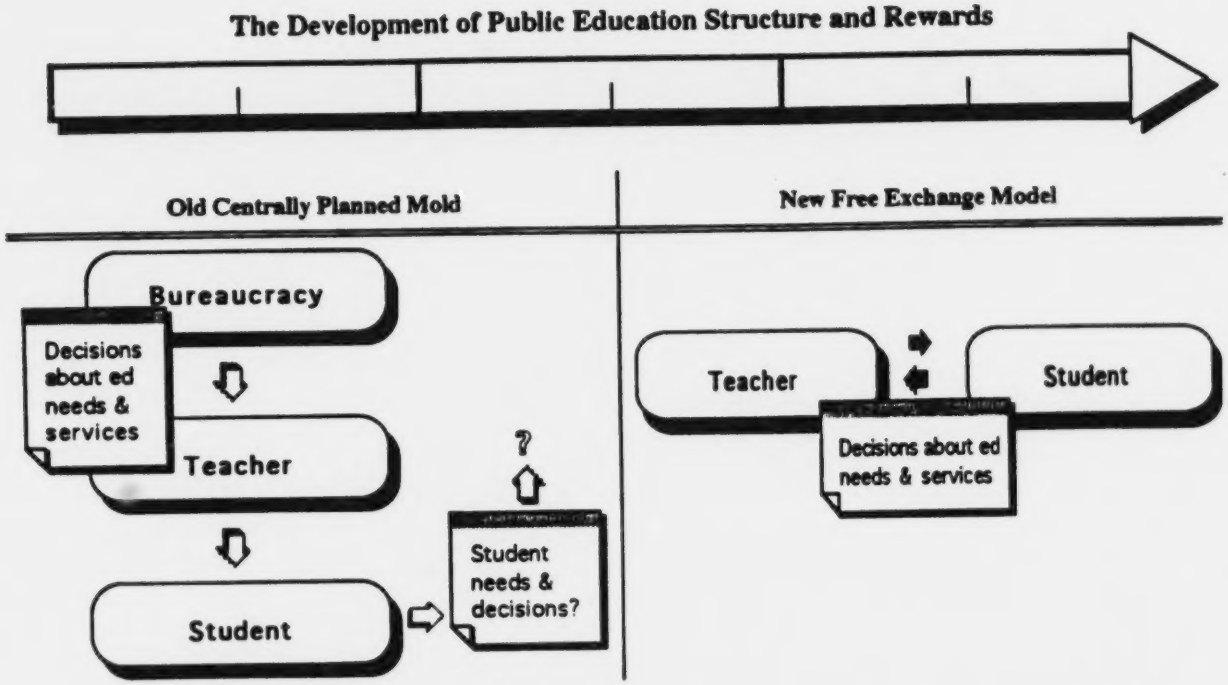


Old Centrally Planned Mold	New Free Market Model
• Central planning is necessary to insure adequate goods & services, fairness of rewards	• Systems are self-regulating by their own "invisible hand" & produce mutually beneficial relationships; reward of provider connected with benefit to consumer
• Centralized government ownership of the means of production provides efficiency & quality	• Decentralized, participant controlled exchanges produce increasing quality/productivity for decreasing costs
• Standardization & uniformity are fairest & best for all	• Systems of exchange naturally produce diversity, specializations, & cooperations

Management theorists are almost as one in decrying bureaucracy. What is important here is the mechanism of change itself. What would naturally produce the development of a system from the left to the column on the right above?

Bureaucracies thwart the healthy and free interchange between the teacher as provider and the student/parent as consumer of education services. Funds for payment of instructional services must filter down to the teacher through the bureaucracy rather than coming directly from the student. Rather than student determination of education goals, the government decides. Instead of teachers motivated by the development of professional competence to understand and provide the quality of services students/parents demand, the government interferes by regulation and quality control through standards, rules, testing, certification, and careful oversight by committees and administrators.

The Development of Public Education Structure and Rewards



In the left hand column, public monopoly education attempts to distance teachers from responding to the needs of the student or receiving their rewards from students. By design, public monopolies' teachers react to bureaucratic rules, supervision, and curriculum and in so doing public schools make the bureaucracy the consumer for the teacher instead of the student. The relationships of teachers responding to the needs of students and rewarded by the students are shown in the column on the right.

Rothschild points out that it is not a question of choosing how systems should operate. They do have mechanisms of self-regulation which balance and re-adjust their exchanges. Capitalism is not a decision; it can be repressed, but the need for unfettered human interchange and the natural development of markets (as black markets and the underground press confirm) is not a matter of choice. It is not up to us to choose whether or not the principles of free human interchange exist. Rather, the choice is in whether to permit a healthy free market "to allow society to communicate honestly with itself," or whether to establish a bureaucracy to allow a few to try to police the many.

In student, teacher, and organizational development, the fundamental health of the systems depends on freeing up the natural interchanges and self-regulations that allow them to grow and develop. The easiest place to study these healthy systems at work is in the creativity of a free market or in the healthy explorations and cognitive constructions of a young child. The free market provides a powerful exemplar for understanding and designing a system in which education providers are released to develop specialized services for consumers, and consumers are freed to reward those providers they value and choose. It is only in such a free market with the exchange of valued ideas that the healthy development of students and teachers can occur.

Part 5: Budget

Some see private enterprise as a predatory target to be shot, others as a cow to be milked, but few are those who see it as a sturdy horse pulling the wagon.

Winston Churchill

BUDGET: ADDING A KEY INCENTIVE

The detailed 5 year budget, submitted in the proposal to NASDC, shows larger funding for the initial design and testing years with decreasing amounts requested as the EDC begins to earn revenues from schools and profits from its own success. A key incentive almost entirely missing from American education is the profit motive. In America, individuals can generally profit from their hard work, ingenuity, creativity and risk taking but these are not encouraged in education today. However, we treat the NASDC award as a business opportunity, and not just a grant.

The contract being sought to fund *Marketplace Schools* development will thus be granted to a for-profit Education Development Corporation set up and controlled by the principals of this proposal. Rather than have the contract go to Cascade Policy Institute or Institute for Developmental Sciences, both non-profits, it will be used by the EDC to further develop *Marketplace Schools* and demonstrate that entrepreneurs can profit by doing education right.

To maximize the effectiveness of the NASDC grant during the years that grants are awarded, all EDC profit earned from the grants will be retained in the corporation and used for *Marketplace Schools* development. Profits earned from other contracts with schools, professional group practices, etc. will be treated as normal corporate profits and distribution will be decided by the EDC Board of Directors. Earning a profit at education will be one of the clearest signals for others to adopt a *Marketplace Schools* approach.

PRIMARY DESIGN PRODUCTS

NASDC will receive and monitor, in developing form, products describing the development and operation of a complete free enterprise model of public education. Included will be samples of documents, evaluation instruments, budgets, charters, articles of incorporation, etc. The NASDC phase one design contract will produce three up-and-running lab school sites in two states all moving toward becoming professional group practices and research and development professional group practices and our fully functioning EDC. The deliverable products to NASDC will be:

- √ *Student Development Handbook* for teachers with sections for parents
- √ *Teacher Development Handbook* for teachers, researchers, and teacher developers
- √ *PGP Handbook* for developing and operating professional group practices
- √ *EDC Development Handbook* for developers of *Marketplace Schools* and EDCs

√ *Development Handbook* for the disseminating new *Marketplace Schools*

Each handbook contains background materials of sources and references for the developmental sciences, organization theory, and bionomics.

Management of the Design Process with Subcontracts by EDC

The design process begins by establishing the Educational Development Corporation which will develop the design. The heart of the design process rests with the principal designers but the extensive variety and talent of the total design team provides a tremendous resource. The EDC directly supports the principal design effort but besides the design, the EDC also manages the sub-contracts, develops the handbooks, manages the lab school site contracts, searches the literature, issues individual contracts, manages the funds, and establishes the network.

Site-Based Design Process

The teachers from our three lab school sites develop two new roles: (a) that of a professional educational service provider affiliated with other teachers in a professional group practice and (b) that of master professional researcher/teacher providing design and possibly research.

These schools are the design teams' laboratories for specific classroom problems and general systemic issues of freeing schools from the bureaucracy. Lab sites assist by contracting to study specific contracts and one general problem, that of changing all or part of their public school into a professional group practice which is cut free from the bureaucracy. This site contract will be one which assists the design team in developing the concept of the professional group practice and the PGP as an R&D site. With three sites, we will have distinct features emerge. The products from this phase will be combined into four milestones with design reports describing three contract relationships among participants:

- The relationship between teachers and their PGP—partnership, a voluntary association governed with by-laws, a franchise, etc.
- The relationship between the PGP and the EDC—what services teachers determine they need and would purchase from some form of EDC
- The relationship between the EDC and teacher researchers

Specific design contracts may cover any of the particular subsystems in each of the *Handbooks*.

Developing the Design of Student Learning

At the heart of the site based design process is teachers' focus on understanding and promoting students' discipline based development. Teachers assist in designing the system for generating student learning activities in each of the disciplines, how activities are managed with student contracts and portfolios, developmental evaluation of students' understanding in each of the disciplines, and the contract relationship with students/parents which coordinates long range growth plans and other design aspects for which they may accept contracts. The design process does not depend on site-based research but we believe it will quickly and powerfully refine the design and will develop the R&D function in each school which will be an integral part of any system of *Marketplace Schools*.

Development of the Design for Developing New EDCs and PGPs

Part of the design effort involves procedures for developing educational development corporations and professional group practices at new sites. It addresses the dissemination of a free market system of education in establishing legal and financial relationships with the state and local agencies. Teachers also assist in providing information regarding the design of the teacher information network.

Specification of Handbooks

The following table lists the components of each of the five handbooks:

Components of Each Handbook

Student Development	Teacher Development	Pro Group Practice Development	Ed Development Corporation	Implementation of Marketplace Schls
1. Long Range Education Plan	1. Tchr/Stdnt Legal Contracts	1. PGP/Tchr Contracts	1. Concepts of Contracting	1. State Monopoly & Free Market System
2. Learning Contracts	2. Stdnt Long Range Ed Plans	2. Personnel & Membership	2. PGP Development , Franchising, Consulting	2. Federal, State, & Local Laws & Regulations
3. Mathematical Development	3. Tchr Dev--Curriculum & Disciplines	3. Powers, Types, Charters, Decision Making	3. Operation Services to PGPs	3. Relationships with Higher Education
4. Mathematical Activities	4. Tchr Dev—Instruction & Student Contract Learning	4. Internal Operations	4. Teacher Information Services & Network	4. State, Local, & Individual Funding
5. Science Development	5. Tchr Dev— Stdnt Portfolios & Eval	5. Funding	5. Teacher Ed, Cont Ed, Internship Services	5. EDC Method of Dissemination
6. Science Activities	6. Community Resources	6. Marketing	6.Marketing Services	
7. English Development	7. Adult Learning	7. Facilities, Site Development	7. Public Portfolio, & Ac'tblty System	
8. English Activities	8. Teacher Researchers and Developers	8. PGP Public Portfolio	8. EDC Structure & Operation	
9. Geography Development	9. Financial Management		9. EDC Personnel	
10. Geography Activities	10. Professional Public Portfolio		10. Dissemination & Dev Services	
11. History Development			11. Stdnt, Tchr, System Research & Develop	
12. History Activities			12. Teacher Researcher Contracting	
13. Other Disciplines			13. Teacher Developer Contracting	
14. Other Student Activities			14. Funding,& Financial Accountability	
15. Student Public Portfolios			15. EDC Public Portfolio	

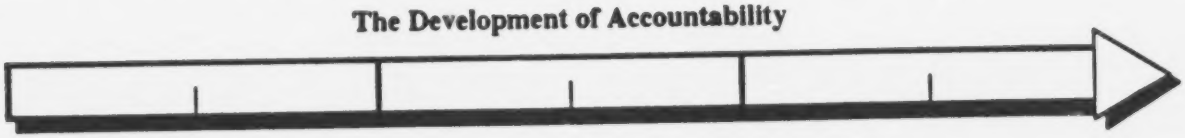
To assist NASDC's research and analysis contractor and to provide a framework for our own system of contract management with our subcontractors, the following table outlines how

the management system establishes milestones and benchmarks for each of the components of the handbooks. In these summary tables, we show only the benchmarks for the overall handbooks.

	1st Milestone July 15, '92	2nd Milestone Oct 15, '92	3rd Milestone Feb 1, '93	4th Milestone Jun 30, '93
STUDENT DEVELOPMENT	Preliminary concept papers describing parameters & design specifications	First design paper describing rough outlines for possible design along with initial literature	Designs incorporating trial results, lab site information, and literature reviews	Designs incorporating critiques, revisions, and tests
(15 COMPONENTS)	Each of the 15 components has benchmarks and milestones for subcontractors to complete work. These are not designs for NASDC but preliminary information from the field for use by the Design Team. The Design Team uses the information as part of the design process to establish precise descriptions and benchmarks of student development in each of the disciplines and design the other components.			
TEACHER DEVELOPMENT	Preliminary concept papers describing parameters & design specifications	First design paper describing rough outlines for possible design along with initial literature	Designs incorporating trial results, lab site information, and literature reviews	Designs incorporating critiques, revisions, and tests
(10 COMPONENTS)	Each of the 10 components has benchmarks and milestones.			
PROFESSIONAL GROUP PRACTICE	Preliminary concept papers describing parameters & design specifications	First design paper describing rough outlines for possible design along with initial literature	Designs incorporating trial results, lab site information, and literature reviews	Designs incorporating critiques, revisions, and tests
(8 COMPONENTS)	Each of the 8 components has benchmarks and milestones.			
EDUCATIONAL DEVELOPMENT CORPORATION	Preliminary concept papers describing parameters & design specifications	First design paper describing rough outlines for possible design along with initial literature	Designs incorporating trial results, lab site information, and literature reviews	Designs incorporating critiques, revisions, and tests
(15 Components)	Each of the 15 components has benchmarks and milestones.			
DISSEMINATION OF *MARKETPLACE SCHOOLS*	Preliminary concept papers describing parameters & design specifications	First design paper describing rough outlines for possible design along with initial literature	Designs incorporating trial results, lab site information, and literature reviews	Designs incorporating critiques, revisions, and tests
(5 COMPONENTS)	Each of the 5 components has benchmarks and milestones.			

Part 6: How We Will Know If It Works

The Development of Accountability



Old Mold Accountability	New Model Self-Regulation
• Testing to meet pre-established standard	• Natural self-regulations of marketplace
• Boards, supervisors insure oversight & maintenance of standards	• Multiple providers & market competition discriminates against consistently poor quality
• Rules, standards, tests to determine & correct errors, gaps, or poor performance of participants	• Public critiques, comparisons, & free flow of information provide constant self-feedback & self-correction

Evaluation Policy

NASDC's goal is break the mold student performance, but we believe NASDC also understands that even break the mold school performance on tests is a means to the larger goals of each individual and our American society. While perhaps there is a core of knowledge common to the idea of democracy and our American culture, we remain strong because our citizens understand how to actively investigate and take ownership of civic problems, new developments in their career fields, and social and interpersonal life. **Knowledge is not what makes us strong, but the ability to confront problems and create anew.** It is American invention and creation which builds our lives and our nation.

Education must therefore direct itself to the constructive roles adults must play. The success and evaluation of schooling must be directly tied to the adult success of its students. The primary focus of evaluation systems must be anchored in the long range individual success of our students.

Measurement of Student Growth

Adult Role Success of Students

- In their permanent portfolios, students voluntarily provide whatever evidence they feel demonstrates their best work and documents capabilities to successfully assume personal, career and civic roles as adults. Contents are factual, not judgmental or evaluative, can be changed, and are intended to provide the best features of the student.
- For documenting family and interpersonal role development, the permanent portfolio might contain descriptions of positions of leadership, group work, management skills, parenting classes and organizations, religious participation,

job descriptions, work group participation, etc. Career and civic development are documented in like manner (civic organizations, politics, community work, learning community, Alumni involvement, business support of learning, citizen boards, etc.)

- The permanent portfolio is used and maintained at the EDC until age 25 as part of the public information system and is available for use by parents, researchers, prospective employers or higher education, etc.

Student Academic and Independent Learning Development

- Students place documentation of significant learning products in their short term portfolios to demonstrate important intellectual understandings and accomplishments and also to document their developing ownership and ability to independently pursue learning. These focus on understanding the basic structure and concepts of math, science, geography, history, and English.
- Daily work organized under learning contracts is private between teacher and student.

The Development of Teachers and Organizations

Teacher Development

- In teaching portfolios, teachers provide examples of instructional units and learning activities to document the development of their instructional program. These portfolios provide descriptions of instructional methods, curriculum, the learning activities, and evaluation methods.
- Teacher portfolios are maintained by the EDC as part of the education public information system and as extremely useful information for teacher development coursework, clinical assistance, and research by the EDC.

Organizational Development

- Organizational development is also documented in the professional group practice's (PGP) portfolio. The documentation describes the philosophy, instructional capabilities and specialities, samples of student projects, and long range results of the students' of the PGPs.
- The EDC must also document its own development through a portfolio open to critique by the public. The EDC documents its activities and its development by the use of qualitative benchmarks.

Special NASDC Comparative Measures

We added three old mold evaluation instruments to insure the widest possible comparisons and analysis of the success of *Marketplace Schools*.

- *Standardized Tests*—We will use national or international measures tied to key understandings of the basic subject areas to measure the overall progress of our students at ages 9, 13, and 17.

- *Demographics and Background Variables*—Considerable variance in test scores is contributed by factors other than schooling, and, in fact, schooling effects are relatively difficult to isolate. Measurement of relevant background data on students allow a data pool for researchers. For our purposes, we believe the tiny bit of research evidence available suggests a focus on basic intellectual development and understanding will produce substantial effects on standardized tests, so we will be interested in the long range change in the standing of our students relative to national norms.
- *Initial Student Achievement*—Initial student achievement is a powerful predictor of later student achievement. It will be measured to allow for meaningful comparisons with other schools.

The Importance of Developmental Evaluation

Monopoly government control of schools and top-down flow of incentives and rewards creates the need for top-down imposition of standards and enforcement, accountability means tough standards and close scrutiny through increased testing and oversight. Providers in the free market are naturally regulated by the free flow of information and the discussion of quality. We support this natural self-regulation by making non-tangible educational services and intellectual development tangible through the use of portfolios and developmental analysis.

The goal of *Marketplace Schools* is not test scores; it is future success in life. Progress of students in *Marketplace Schools* is measured by the development of intellectual structures leading to success rather than meeting predetermined testing end points at certain grades.

The system of public scrutiny used in *Marketplace Schools* will provide more accountability than other schools since (1) both the actual work plans and accomplishments of students and teachers are held up to public scrutiny, (2) the public as consumer becomes an integral part of examining actual operations rather than just test scores, (3) *Marketplace Schools* use both qualitative and quantitative evaluations to monitor, not govern schooling, and (4) in an open environment, a teacher who does not offer or deliver a quality service will not attract clients.

Part 7: How We Will Persuade Others to Put Our Design In Place

Marketing Our Concept

For dissemination, we use a marketing, not a reform model. Rather than a massive top down reform model, ours is a ***developmental model*** which will start small, just as any entrepreneurship begins small, and would grow only with success in finding a market niche. Initial start-up seed money for the Educational Development Corporation will establish four functions:

- Provide initial resources for development and start up costs for the initial professional group practices and the Educational Development Corporation
- Establish a temporary R&D agency to act as a system-wide resource to provide development support and react to unanticipated contingencies
- Protect the independence of the new educational ecosystem so that it can grow free from the educational bureaucracy
- Remove some of the financial risk for initial participants

Marketplace Schools are easy to market because people get to choose and participate in their creation in contrast to government schools. *Marketplace Schools* can be marketed as an alternative for teachers and students, particularly those with underserved or specialty needs. States and districts may use the *Marketplace Schools* to establish R&D lab schools for stimulating change in education. State leaders may use *Marketplace Schools* with their built in R&D and networking by the EDC as a system of R&D lab schools in which to ask and answer policy questions such as those regarding equity or the comparative differences in efficiency and quality between government owned and free market schools.

Marketplace Schools offer interesting additional opportunities for local communities to provide additional education resources and local control free from the state specifications. Teacher unions value the concept of lab schools operated by professional teachers. Communities can use *Marketplace Schools* to focus on special needs such as establishing high powered math and science centers, alternative schools for dropouts, special education, or to build on existing reform programs. Entrepreneurial teachers can use *Marketplace Schools* as a planned way to begin small and gradually develop a successful business. Districts can use *Marketplace Schools* as an alternative method for reacting to particular community needs. They can have "easy entrance, easy exit" by determining what portion of their student tuition they might release. Participating districts and states can also use *Marketplace Schools* as leadership opportunities in programs or research.

A market share of 32% could spell success in business but is certain disaster at the polls. *Marketplace Schools* are unlikely to achieve a majority vote in the polls but they are an easy product to sell. We don't have to persuade a majority. We have a niche to fill, and we avoid

competition by finding an unfilled niche. *Marketplace Schools* have something in them for everyone, and they are easy to market because people have the freedom to choose.

By establishing mutually beneficial relationships between providers and consumers, the principles of natural growth and development will allow a proper balancing between bureaucratic and entrepreneurial models of public education without using legal coercion or regulation. *Marketplace Schools* will provide a yardstick against which to measure the rest of the system. If *Marketplace Schools* are able to offer an attractive and successful alternative to the public bureaucracy, they will gradually and naturally grow and develop to include more teachers and parents as they opt out of the educational bureaucracy.

The question is not "How do we change our schools?" The question is "How do we change the structure and rewards of schools so they change themselves?"

SUPPORTING DOCUMENTS

"Time to Shift the Paradigm"

Remarks delivered to the

Mont Pelerin Society

by Michael Rothschild

Author of *Bionomics*

Big Sky, Montana • August 23, 1991

In the next twenty minutes, I'd like to accomplish three objectives. First, I'll explain why we need a fundamentally new way of thinking about the economy. Second, I'll give you a sense of the new theory that I call the bionomic perspective. And third, I'll sketch out a few implications of bionomics.

My first task is to convince you that we need to rethink our most basic assumptions about economics. I realize that this is a position that an audience peppered with prominent economists is not likely to endorse. But allow me to explain my reasoning.

Just two days ago, with the collapse of the coup in Moscow, we all experienced an enormous sense of relief. The front page of yesterday's *Wall Street Journal* declared that the path was now cleared for a real transition to Soviet capitalism. As in those days just after the Berlin Wall collapsed in November 1989, there is a feeling of jubilation in free market circles, a belief that the Wicked Socialist Witch of the East at last is dead.

Unquestionably, the events of the last week are cause for celebration, but I believe a note of caution is still warranted. As a *practical* matter socialism has indeed collapsed, but as an *intellectual* force, socialism is still very much alive. And I, for one, will not feel safe until the intellectual case for socialism has been obliterated. This, I maintain, is the most important unfinished task confronting those committed to individual liberty and economic freedom.

To bolster my point, permit me to read a key passage from Friedrich Hayek's 1949 essay "The Intellectuals and Socialism."

> There can be little doubt that the manner in which during the last hundred years man has learned to organize the forces of nature has contributed a great deal toward the creation of the belief that a similar control of the forces of society would bring comparable improvements in human conditions. That, with the application of engineering techniques, the direction of all forms of human activity according to a single coherent plan should prove to be as successful in society as it has been in innumerable engineering tasks, is too plausible a conclusion not to seduce most of those who are elated by the achievement of the natural sciences. It must indeed be admitted both that it would require powerful arguments to counter the strong presumption in favor of such a conclusion and that these arguments have not yet been adequately stated. It is not sufficient to point out the defects of particular proposals based on this kind of reasoning. The argument will not lose its force until it has been conclusively shown why what has proved so eminently successful in producing advances in so many fields should have limits to its usefulness and become positively harmful if extended beyond these limits. This is a task which has not yet been satisfactorily performed and which will have to be achieved before this particular impulse toward socialism can be removed.

In my view, despite the advances made in economics since Professor Hayek penned these words, his point is just as true today. Those who believe in economic freedom have failed to construct a coherent and compelling argument that completely demolishes the socialist mythology. Even after socialism's decay was revealed by the fall of the Iron Curtain, Western intellectuals—in academia, in government, and in the media—are still overwhelmingly sympathetic to the basic ideas of socialism.

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Some will now grudgingly admit that capitalism is more productive, but they continue to believe that socialism holds the intellectual and moral high ground. And, because the supporters of economic liberty have been unable to eradicate this misperception by force of argument, advocates of economic freedom remain a distinct minority within Western intellectual circles.

The collapse of socialism resulted from its own inherent unworkability—a truth first explained by Ludwig von Mises nearly 70 years ago. *But explaining why socialism would fail is not at all the same as explaining why capitalism works.* As Professor Hayek put it, "these arguments have not yet been adequately stated."

This brings us to the central question. With so much evidence of capitalism's superiority, why hasn't an overwhelmingly forceful case for free markets been made? In my view, the answer is rather simple. Despite their many superficial disagreements, at the most fundamental level, economists of the Left and the Right accept the same basic paradigm. From a time well before economic thinkers split into the factions of the Left and Right, from the time of the classical economists themselves, economic thinkers have conceived of the "economy as an equilibrium machine." Because economics emerged in an era when Newtonian physics dominated the intellectual landscape, economics became the social science version of Isaac Newton's mechanistic system.

Like the classical physics upon which it is based, classical and neo-classical equilibrium economics describes the world as if it were an eternally unchanging, cyclical clockwork mechanism. In the Newtonian system, once the trajectories of the planets are known, time is merely a variable in the precise calculation of their future positions. But taken as a whole, the Newtonian universe is static, timeless, and therefore perfectly predictable—just like a machine. The predictability promised by the Newtonian vision proved irresistible to economic thinkers who sought to achieve the status of a true science for their discipline. In pursuit of this goal, attention to messy empirical reality was sacrificed. Notions of balance, equilibrium, and cyclicality—all borrowed from Newtonian mechanics—became the central myths of mainstream economics.

When it comes to proving the relationship between Newtonism and socialism, we need look no further than Hayek's 1941 article *The Counter-Revolution of Science.* There he showed conclusively how the writings of Saint-Simon and Comte, which so influenced Karl Marx, were an attempt to create a "social physics." The Marxist vision of society as a gigantic economic machine, with the state as its controller, owes its existence to Newtonian thought.

Similarly, the intimate relationship between Newtonian physics and classical and neo-classical economics has been thoroughly documented by Ingrao and Israel in their recent book *The Invisible Hand: Economic Equilibrium in the History of Science.* But to see the relationship, one need only recall the praise that John Maynard Keynes heaped upon Alfred Marshall's general equilibrium model when he described it as: "a whole Copernican system, by which all the elements of the economic universe are kept in their places by mutual counterpoise and interaction."

In short, the differences between the leading orthodox schools of economic thought have not been differences over first principles. They have been disagreements over exactly how the "economic engine" operates, how it can be made to run faster and smoother, or—to use their favorite phrase—how it can be "fine-tuned."

With the notable exception of the Austrians, no one seemed to question whether the economy was an engine in the first place. But even the Austrians, as admitted by Hayek himself, had not been able to take the next crucial step. Even they had not put forward the new theory that could go beyond their devastating critiques of "economics as physics." In this connection, the words of Mark Blaug, the eminent historian of economic thought, are worth noting. Professor Blaug wrote:

> Bad theory is still better than no theory at all and, for the most part, critics of orthodoxy have had no alternative construction to offer. . . The moral of the story is simply this: it takes a new theory, and not just the destructive exposure of assumptions or the collection of new facts, to beat an old theory.

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Time to Shift the Paradigm

Simply put, *Bionomics* is my attempt to satisfy Professor Hayek's call for "powerful arguments to counter the strong presumption in favor of" socialism, and to meet Professor Blaug's demand for "a new theory. . . to beat an old theory." It is for readers like you to judge whether this effort has been successful.

Now, I will not try to compress the argument made in a richly detailed 350 page book into a few minutes. It can't be done. To appreciate the full power of the bionomic argument, you'll have to read the book. Here, I will merely try to give you a sense of bionomics.

Instead of "economy as equilibrium machine," *Bionomics* describes the "economy as an evolving ecosystem." Both the ecosystem and the economy are examples of what the new non-linear sciences of complexity call "self-organizing, chaotic" processes.

Bionomics holds that, like an ecosystem, a market economy is a natural and spontaneous evolutionary process. Neither of these exceedingly complex systems was planned. Neither requires central management. In fact, because both systems are so complex and ever-changing, attempts to consciously manipulate either one tend to have highly destructive, though unintended, consequences.

Briefly stated, coded information is the essence of both systems. In the biologic environment, genetic information, encoded in the DNA molecule, is the basis of all life. In the economic environment, technological information, recorded in books, blueprints, scientific journals, formulae, algorithms, and databases, is the source of all economic life.

As mankind's ability to copy and exchange information improved, first with the invention of the printing press, and more recently with the creation of the computer, the accumulation of scientific knowledge quickened and then accelerated again. Today, a staggering profusion of highly specialized organizations—from fast-food chains to microchip makers to international airlines—employ tiny subsets of this vast body of coded information to convert raw materials and labor into the finished goods and services that satisfy human needs and desires.

Although the pace of economic evolution is stunningly rapid, its detailed processes are remarkably similar to those found in nature. Slight rearrangements of genetic code, known as mutations, are much like the modest alterations of technologic code, known as improvements. Major revisions of genetic code sequences, called recombinations, are analogous to the radical changes in technologic code called inventions.

In nature, new sequences of genetic code (manifested as organisms) which "fit" the environment are sorted from less efficient strains by natural selection. Similarly, certain new technologies (manifested as business organizations) are distinguished from less effective alternatives by market competition. The chief difference between the biologic and economic forms of information evolution is speed. Conscious technologic change happens several million times faster than random genetic change.

To make clear what bionomics is not, it is necessary to distinguish bionomics from social Darwinism. Ultimately, the perverted logic of social Darwinism led to the eugenics movement and to one of the greatest tragedies in history—the Nazi Holocaust. Because of this horrifying result, biology became taboo for economic thinkers. *Bionomics* reopens this closed subject by arguing that the insights of modern biology, *properly applied*, can shed new light on the complexities of the economy.

Unfortunately, the appropriate use of biology's lessons in deciphering human social questions has been complicated by the recent rise of human sociobiology. Proponents of this view employ far more sophisticated language than old-fashioned social Darwinists, but the core allegation is the same—people are born to behave the way they do. Supporters of human sociobiology see the diversity of human cultures as rooted in differences within the human gene pool. For them, culture does not emanate from the mind, but from the genes.

In sharp contrast, bionomics holds that economic development—and the social and cultural change flowing from it—is not driven by a society's genes, but by its accumulated technical knowledge. Technology, not people, holds center stage in bionomics. Indeed, wherever advanced technologies have penetrated, cultural chasms once thought unbridgeable have narrowed to the vanishing point. Europe's current unification is but one example of this common process. Throughout human history, profound cultural change has

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been driven by the evolution of technological information, not the evolution of genetic information. Our genes have gone virtually unchanged for 200,000 years.

Our genes do not program us to become capitalists. The system we call "capitalism" is not an "ism." It is not a belief system, like socialism. Capitalism is simply the process by which coded technological information evolves. To accept the premise that capitalism is merely an alternative to socialism, is to lose the argument before it begins.

Human beings are the only agents of technological evolution on this planet, because we alone are biologically equipped to read and write. By virtue of an immensely long string of evolutionary accidents, we happen to be the only species able to code and decode strings of symbols stored outside our bodies. It is this unique capacity which has made us scientific and economic beings.

Needless to say, the bionomic perspective has far-reaching theoretical and policy implications. Among other things, bionomics will help close the yawning chasm that separates economic theory as taught in the universities from economic experiments as conducted in daily business life. Indeed, the concepts which form the logical backbone of bionomics were derived not from axiomatic reasoning or mathematical abstraction, but by searching everyday business life for common patterns, and finding that parallels to these phenomena had already been articulated by those working in the biological sciences.

Most importantly, I believe the bionomic argument has the persuasive power that Professor Hayek saw as so essential in the struggle to finally extinguish socialism. To paraphrase his words, bionomics "conclusively shows why the engineering approach that has proved so successful in so many fields is positively harmful when extended to human society."

We need only review our disastrous attempts to manipulate nature to see why we cannot possibly expect to successfully manipulate the economy. One reviewer of *Bionomics* put it rather nicely when he wrote: "If capitalism is a Brazilian rain forest, then socialism is a zoo." Socialism is planned, neat, and organized, but it is devoid of complexity, diversity, vitality, and even the capacity to reproduce itself. "Economy as machine" thinking leads inexorably to a "command-and-control" mentality. A shift from the machine to the ecosystem metaphor will turn the political tables on the interventionists. For the first time, they will be forced to overcome the presumption that their programs, however well-intended, will do damage to our delicate economic rainforest.

I believe that the logic and rhetoric of bionomics offers the advocates of economic freedom powerful new weapons. Now that socialism *per se* has collapsed, its proponents have moved on to do battle against individual freedom by taking up the morally unimpeachable banner of environmentalism. My fear is that without the use of the bionomic argument, free market forces will find themselves bogged down again, in another decades-long struggle of ideological trench warfare. As in the past, they will be logically and empirically correct, but unable to make the kind of persuasive case that changes attitudes in the political mainstream and thereby changes the direction of public policy.

But now that the bionomic argument does exist, my hope is that others will use it in the battle against the so-called "Red-Greens" by arguing that a capitalist economy is *itself* an ecosystem, that environmentalism based on "command-and-control" government regulation will inevitably disrupt and do grievous harm to both the economy and the ecosystem. We just can't treat a living thing like a machine and expect it to flourish. To grow our economy while protecting our environment, we must be sensitive cultivators, not arrogant manipulators.

And finally, it is my hope, now that the citadel of socialist power has collapsed in Moscow, that *Bionomics* will persuade intellectuals around the world that the very idea of socialism is profoundly wrong, that the only path to human prosperity and ecological integrity is the path of economic freedom.

Michael Rothschild
The Bionomics Institute
2173 Francisco Blvd., Suite C
San Rafael, CA 94901
Phone: 415-454-1800
Fax: 415-454-7460

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Evaluation Report 238.13 of the
DEVELOPMENTAL ASSESSMENT PROJECT to the
OREGON CADRE FOR ASSISTANCE TO SCIENCE (OCATS)

A Developmental Baseline Profile of 12 Key Elementary Science Concepts/Processes

by
Richard Mennhard

June 25, 1990

THE INSTITUTE FOR DEVELOPMENTAL SCIENCES
3957 E Burnside, Portland, Oregon 97214
(503) 234-4600

and to explore the usefulness of this information with the staff.

OBJECTIVES

The objectives of the project were to produce:

(a) a simple summary of students' developmental level by grade level in five areas of science,

(b) a summary of student development for each grade level for each of several concepts,

(c) a K-5 overall school growth description, and

(d) an opportunity for the OCATS Elementary Concept/Process-Based Science Project school staff to observe and discuss the differences between developmental methods and performance-based methods of measuring student growth.

The OCATS Developmental Assessment Project also provided experience and information which may be of interest to many teachers, educators, and administrators around the state regarding the nature, feasibility, and usefulness of developmental assessment of student growth.

Method

PROCEDURES AND RESPONSIBILITIES

1. The Concept/Process-Based Science Project school principal insured proper assessment authorization had been obtained from parents and all staff understood that student specific results were confidential and would not leave the school. Since this developmental assessment was not for the purpose of individual student diagnosis, results were not posted to student records. All results (except for information on the confidential control roster) are reported only by number and grade level.

2. The Concept/Process-Based Science Project school staff identified six students at each grade for assessment. They were asked to stratify their sample by achievement level--to identify two high achieving, two average, and two low achieving students. This achievement stratification allowed the scores to provide data for inferences about the range and median developmental level of each grade level. Students were tested in random order without knowledge of achievement level.

3. Teachers told participating students how the assessment procedures would work. None of the assessment tasks involved abstract symbolization or writing; all involved direct contact with objects.

5. The researcher provided materials and administration for the assessment.

6. The researcher provided a preliminary briefing and after school debriefing opportunities for teachers and other interested staff. Teachers were free to use this as an opportunity to study the administration of developmental assessment.

7. The Concept/Process-Based Science Project school staff provided a review of this report and included written comments so as to insure accuracy, privacy of participants, and compliance with any district policies.

8. The researcher was to prepare the final report and after review by the Concept/ Process-Based Science Project school staff, release the results to the Oregon Department of Education (ODE) Science Specialist and the Oregon Cadre for Assistance to Teachers of Science (OCATS) directors and other interested educators.

SAMPLE

School personnel at each grade level were asked to use their standardized achievement test score results to choose three sets of two students who would represent high, medium, and low achievers. This procedure produced an 'epistemic' rather than a random sample of students so as to reproduce the representative range of development of a concept at each grade level. The sample size was to be 30 students first to fifth grade but additional students were added mostly from the kindergarten level bringing the total to 40 students as listed in table 1.

The intent of the sample is not to represent the student population of the school but to represent the development of a concept/process among the high, medium,

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and low achievers. The results therefore cannot be generalized to make any statements about school, program, or instructional performance but only about the development of particular concepts at each grade level. By re-assessing the same students in the future, their progress can represent the development of highs, mediums, and lows at each grade level. *Assessment thus reveals conceptual development rather than 'norms' at each grade level.*

TABLE 1
NUMBER OF STUDENTS IN THE SAMPLE
BY GRADE AND ACHIEVEMENT LEVEL

N = 40	GRADE LEVEL					
	K	1	2	3	4	5
Highs	2	3	3	3	2	2
Mediums	2	2	2	1	3	2
Lows	1	3	2	2	2	3
Total	5	8	7	6	7	7

CONCEPTS ASSESSED

The OCATS Developmental Assessment Project measured 12 concepts which sampled five areas of scientific understanding:

- logical-mathematical organization of objects (simple classification, multiplicative classification, seriation, and whole number operations),
- geometrical and spatial relationships of objects (perimeter, area, multiplicative projective relationships),
- physical properties of objects (quantity, weight, volume),
- experimental reasoning (controlling variables in the bending of rods), and
- causal explanation (proportional reasoning in the projection of light).

ASSESSMENT METHOD

The OCATS Developmental Assessment Project used a clinical method of interview based on student interaction with objects to obtain a display and measure of students' understanding.[4] The equipment was given to the student and discussed to insure that students were familiar with names and words which might be used. (The equipment also allowed taciturn students to respond and participate.) A problem was posed which required organization or explanation of the materials, such as classifying, ordering, or explanation of particular causal effects.

For example, to assess understanding of area, students were given a model of a grass field with four barns and some cows. The farmer moves the barns and the student was questioned about whether the cows had more, less, or the same amount of grass to eat. Various arrangements were tried or initiated by students to determine the stability and extent of students' understanding of area.

The nature of students' understanding was then determined by careful questioning which followed the student's method of reasoning. For each task, student responses were analyzed and reported by stage scales.

The time for administering the tasks ranged from about 20 minutes to 45 or 50 minutes depending on the complexity and participation of the student. The tasks were conducted informally so as to put the students at ease, and teachers were encouraged to watch and ask questions as they had the opportunity.

DATA ANALYSIS

The data are summarized by concept by computing the average levels for the high, medium, and low achievers at each grade level. Each concept has a preoperational or intuitive stage, a stage of operational or conceptual understanding, and a formal stage in which the concept is used as a variable in a more complex system of explanatory reasoning. Each stage has an initial substage

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in which the system of mental activity first appears in an unstable and weak form and a generalized, completed form marking the second substage.[5]

The preliminary stage (represented by 0 to 1 on the graphs) refers to sensory motor behavior carried on without significant awareness or representative thought of the activity. Next, Stage IA and IB (reported as 1.0 and 1.5) denote pre-operational thought which is still tied to perceptual states of the activity without rational understanding. The students' understanding forms only a pre-concept at this stage which is unstable as, for example, when the weight of an object increases or decreases with a change in its shape.

Stage IIA and IIB (scored 2.0 and 2.5) signify initial conceptualization and its generalization to all situations. The concept of weight at 2.0 shows an initial conservation of weight in the face of changes in the lengthening of the clay ball but with additional changes, the concept breaks down leading the student to believe weight has changed.

Stage IIIA and IIIB (3.0 and 3.5) denote the use of formal operations. These include qualitative understanding of classes used as variables, volume, the isolation and control of experimental variables, and the causal explanation of light involving a proportional model. Stage IIIA is the qualitative form of the conceptualization while Stage IIIB is the same form re-organized into formal mathematical measurements and representations (formulas).

Results

All students seemed to enjoy the equipment and assessment procedure except for one 3rd grade girl whose aversion to the tasks so great that her assessment was aborted. Initially reluctant, one student was immediately eager to participate after observing another student participating in the tasks. Most students were taciturn and passive, and it made the interviewer work hard to obtain good protocols.

In general, the data showed that it was only at the third grade level and above that students had developed the capability to understand basic rational concepts. These involved simple classifications (grouping and naming things on the basis of similarities), seriations (ordering differences among objects), multiplicative descriptions (using multiple descripters simultaneously), number, quantity, weight, and spatial concepts which are all necessary at the level of simply describing physical objects. The data showed the fifth grade sample as the same or slightly less advanced than the fourth grade sample.

KINDERGARTEN AND FIRST GRADE

Except on one task and for one high achiever, none of the kindergarten sample had as yet put together an understanding of any of the concepts even in an initial Stage IIA form. The first grade sample showed two of the high students with an initial Stage IIA understanding of number, and one student scored unusually high on the classification task. On all other tasks, the assessment showed no rational (Stage II) understanding by students of any of the concepts assessed.

SECOND GRADE

Some of the second grade high achievers showed a stable Stage IIB conceptual understanding of classification, multiplicative classification, or number. Some showed Stage IIA entry level understanding of seriation and multiplication of projective relations. Some of the mediums and lows had initial Stage IIA understanding of classification, and some of the mediums showed initial Stage IIA understanding of projective relations.

THIRD GRADE

The sample at third grade were all well into constructing a solid conceptual understanding of classification, multiplicative classification, seriation, number, and

(except for the lows) quantity. The medium achievers also showed at least the beginning Stage IIA constructions of multiplicative projections. The third grade was marked by an unusual elevation of the lows and mediums resulting in an homogeneity and high level of understanding in the third grade sample.

FOURTH GRADE

The fourth grade highs were solid in their understanding (Stage IIB) of all the concrete concepts (which exclude volume, controlling variables, and proportional reasoning). The mediums were mixed with particular weaknesses in perimeter (length), area, and multiplicative classification. The lows appeared slightly more advanced than the mediums.

The unusual elevation of the lows was due to the remarkable progress of one low achiever student who had put together all of the concrete concepts and was beginning to construct the formal concepts of volume, controlling variables, and proportionality. This low achiever scored at the 2nd percentile for a grade equivalent of 1.7 on the achievement test while scoring with the high fourth and medium fifth graders in development of understanding

FIFTH GRADE

The fifth grade showed slightly less development than the fourth grade particularly in weight and the three areas requiring Stage III formal operations--volume, controlling variables, and proportional explanation. The fifth grade lows had not yet put together an initial Stage IIA conceptualization of multiplicative classification, quantity, weight, or volume, nor did they understand the control of variables or proportional reasoning in their explanations. Unusual was the lack of conceptual understanding of weight by all but one of the fifth graders.

Concept Development Across Grade Level

From the research on student development[6] we know that classification, seriation, number, and multiplicative classification all develop simultaneously but with slight time lags (in the order listed). The development of quantity follows that of number though its development is independent and does not rely on number. On the other hand, weight does depend on the prior construction of quantity and thus always lags behind it. Volume in like manner only follows the construction of weight.

Also lagging behind number and following their own developments comes another two sets of constructions involving projective (how things appear from different points of view, what sections of objects look like, how projections change dimensions, etc) and, simultaneously, Euclidean spatial concepts (concepts involving measurements). The multiplicative projective relations organize spatial relationships among objects and develops at the same time as Euclidean concepts. The concept of perimeter involves qualitative operations of length, and it appears before area.

The development of each of the concepts from kindergarten to fifth grade are presented in graph form on the following pages along with a brief narrative describing the concept, its development, and its relationship to the science curriculum.

THE DEVELOPMENT OF CLASSIFICATION

Classification[7] is a system of mental operations which abstracts and organizes similar properties among objects so that they can be grouped and similarly named.

Every noun depends on a conceptualization process organized by classification since nouns involve the abstraction of common features of elements to which it applies. Understanding names and definitions depend on

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the use of classification operations. The inclusions of classes or concepts can be represented as a hierarchy, Venn diagrams (set circles), outlining, or in language (and are particularly evident in the form of definitions). Adjectives often form subclasses out of nouns.

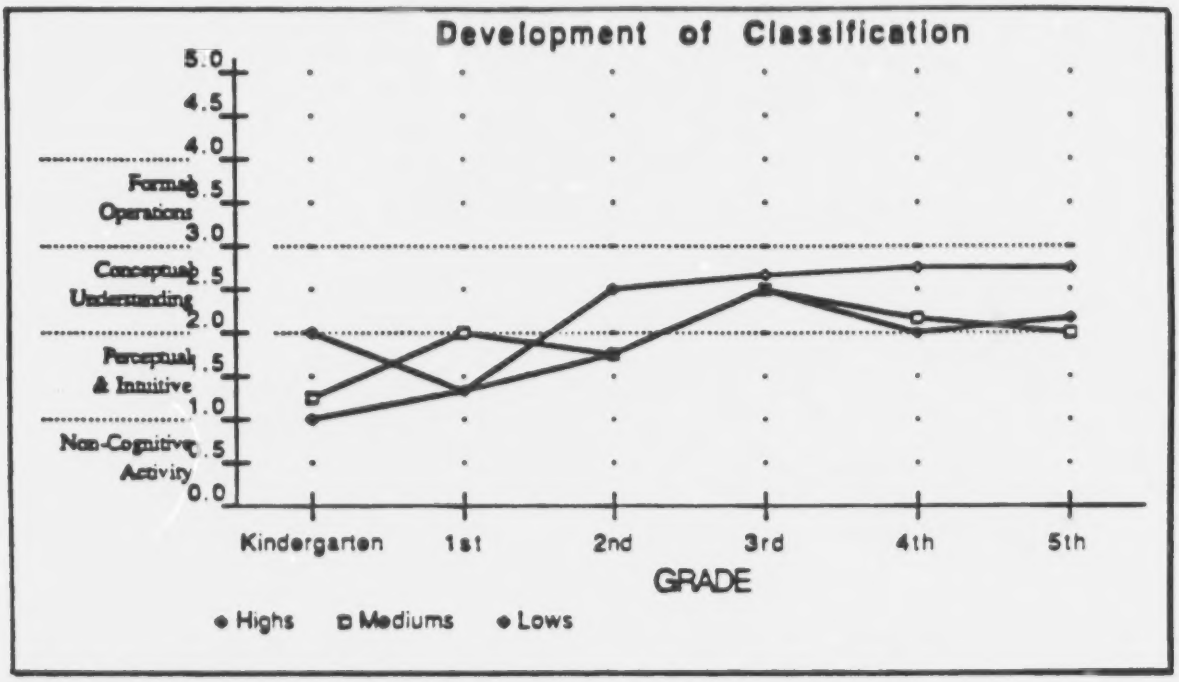

Figure 1: The level of students' understanding of classification from kindergarten to grade five.

Some form of a classification structure is necessary to almost all the understandings specified in the *Oregon Science Curriculum Goals* and most clearly in definitions of all kinds (CCG 1.5, 1.6, 1.14), in understanding all concepts which are quantified (CCG 1.10, 1.13, 1.25, 2.2, 2.4), and in dichotomous keys (CCG 1.11). Classification is most central to science CCG 1.6, 2.1, 2.2, 2.6, and 2.7 and mathematics CCG 7.1.

In the OCATS Developmental Assessment Project classification did not appear as a solid conceptual understanding among a complete grade level sample until the third grade. The high achievers had only a Stage IIA initial understanding of the concept at grade 1 while all the way up to the fifth the lows were still working on constructing an understanding of the concept.

THE DEVELOPMENT OF MULTIPLICATIVE CLASSIFICATION

Multiplicative classification[8] is a system of the natural logic organized by thought to simultaneously use two classification systems to describe objects. 'Land dwelling vertebrates' describes objects using a locational classification system of land and water simultaneously with a structural classification of vertebrates and invertebrates. Multiplicative systems form matrices and can employ either classification, seriation, or a mix ('large, round object' is a logical multiplication of size--a seriation--and shape--a classification--to describe objects).

Multiplicative classification is not specifically addressed in the *Oregon Science Curriculum Goals* (except perhaps in CCG 1.11) although just as with simple, additive classification many goals require it. This is because almost all descriptions and understanding of material objects involve multiple properties. Thus, CCG 1.1, 1.2, 1.6, 1.11, 1.13, 1.17, 1.25, 2.1, 2.2, 2.3, 2.4, 2.12, and 2.13 all address multiplicative classification such as in forming or reading double entry data tables, in the interaction of two variables, and in spatial locational relations.

Multiplicative classification usually develops almost simultaneously with classification. Using two systems simultaneously to describe an object is not conceptually much harder than using one. The findings from this study suggest that all the way up to the fifth grade, the organization of classification in the thought of students in this sample is relatively weak.

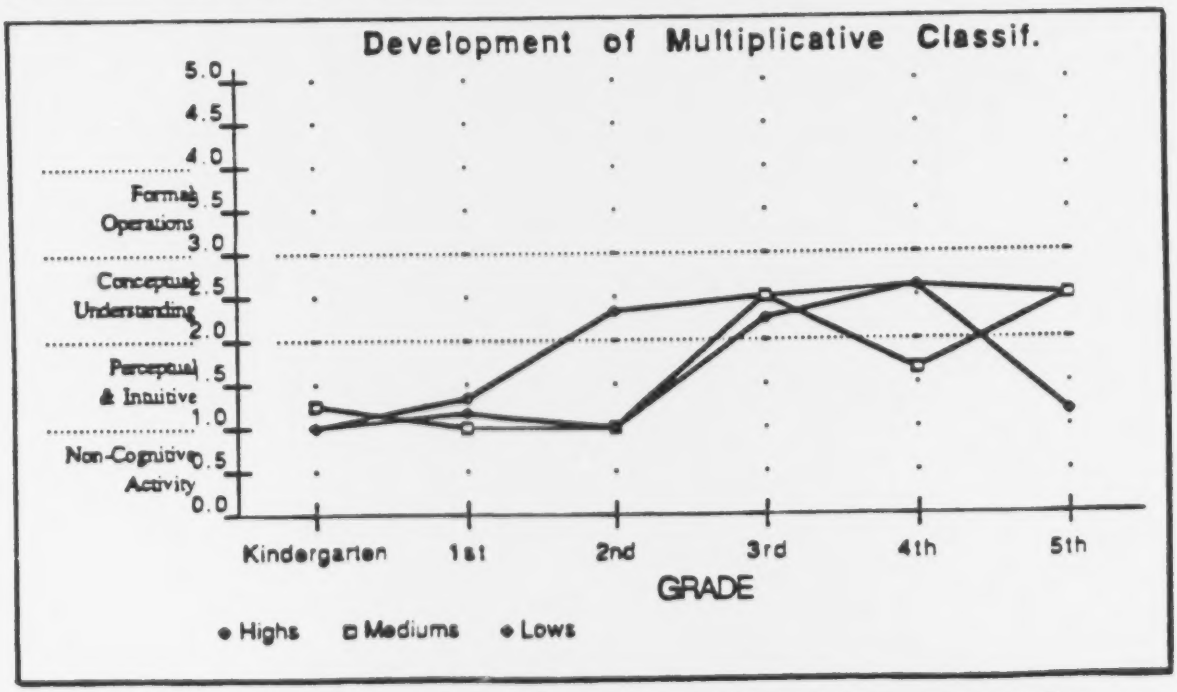

Figure 2: The level of students' understanding of multiplicative classification from kindergarten to grade five.

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THE DEVELOPMENT OF SERIATION

Whereas classification concerns the organization of similarities among objects, seriation organizes differences among objects.[9] All qualities describing objects have degrees of amount or intensity. Weight, temperature, speed, distance, etc. are qualities used to describe ordered differences among objects. The points of seriation often are typified by 'er' words (vectors), heavier, hotter, faster, farther, etc.

Seriation is found in instructional materials anytime ordered differences are used to compare things. Seriation is found forming the understanding of most of the CCG's in parallel with classification. In its strictly logical form, seriation (order) combines with classification (set inclusions) to form number. In understanding a quality such as weight, seriation and classification combine to form a measurement unit. Thus, any CCG which can be scaled or ordered depends on a seriation system as one of its fundamental capabilities. Seriation is most directly addressed in Science CCG 1.6, 2.1, 2.2, 2.6, and 2.7. Mathematics CCG 7.2 addresses seriation.

Seriation develops simultaneously with classification with lags or accelerations dependent on the difficulty of the qualities being addressed. The OCATS Developmental Assessment Project showed the development of seriation closely matched that of classification. Just as with classification, seriation did not appear to be stable and consistent at Stage IIB among any of the grades including fifth grade.

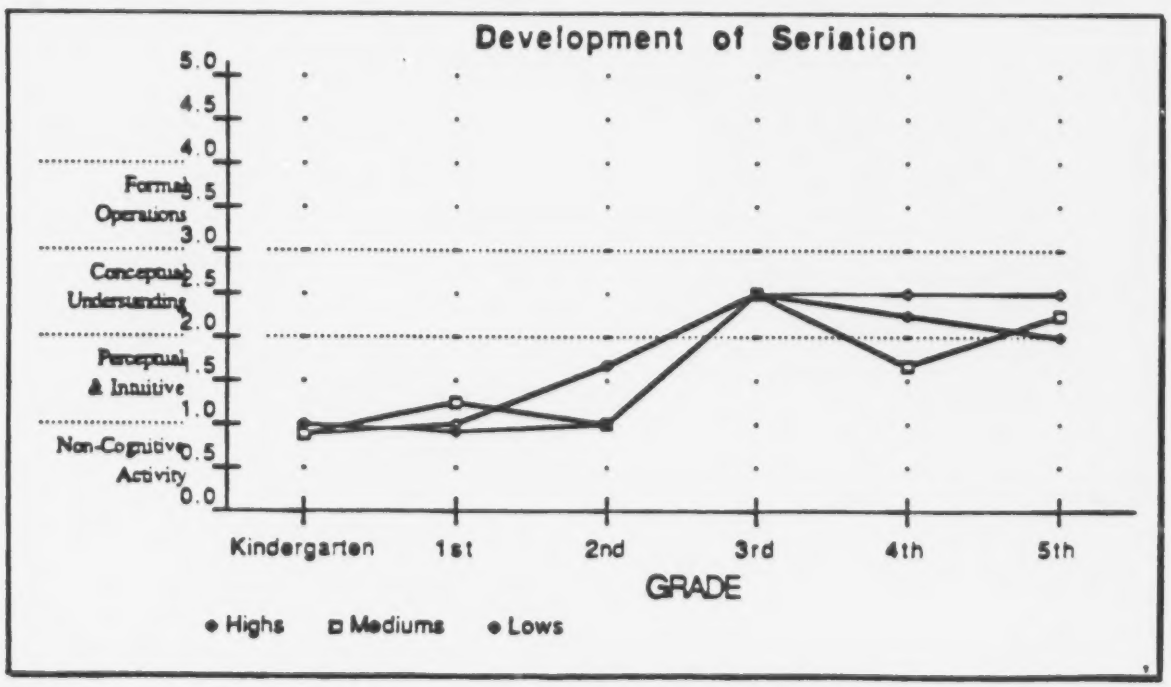

Figure 3: The level of students' understanding of seriation from kindergarten to grade five.

THE DEVELOPMENT OF NUMBER

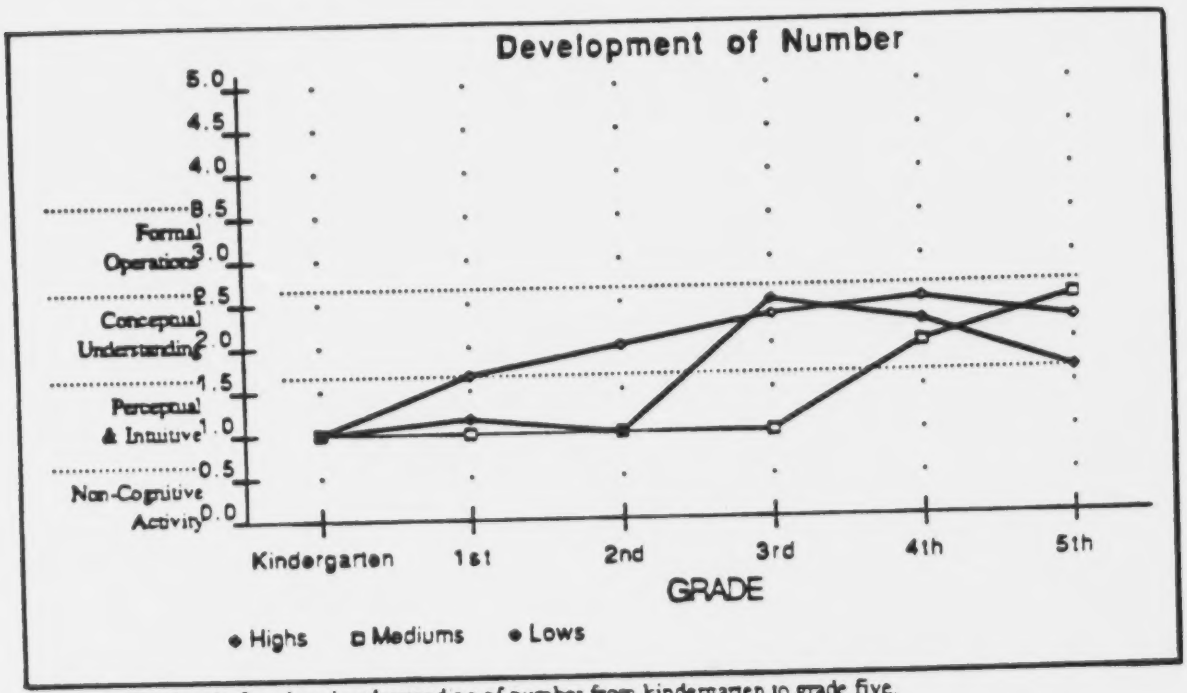

Figure 4: The level of students' understanding of number from kindergarten to grade five.

Number is composed of the coordination of classification and seriation into a single system of units.[10] Construction of a purely abstract numeric unit is not possible for young students of Stage I. They must first organize physical objects themselves. At Stage I, number is constructed by the organization of activity directed to objects but only by treating objects as units without regard to their physical properties. Organizing objects by taking into account their physical properties turns the activity into classification or seriation.

The fact that number develops out of activities of organizing physical objects makes it difficult to maintain a clear distinction between the as yet undifferentiated mathematical and scientific activities of students at the early grades. The first mathematical conceptualization to be developed is the whole number system. This system of mental operations underlies a large number of the functional behaviors specified in the Mathematics Common Curriculum Goals, number and numeration (CCG 1.0), computational skills (CCG 2.0, problem solving (CCG 3.0), mathematical relationships (CCG 7.0), and verbal representation of mathematics (CCG 8.0).

Psychologically number develops parallel to and almost simultaneously with classification and seriation. And it is intimately related to the concept of quantity. In the OCATS Developmental Assessment Project, a conceptual understanding of number appeared at third grade, was stronger at fourth grade, and appeared slightly weaker at fifth grade. Again, none of the grade level samples showed a solid, consistent, Stage IIB conceptual understanding across the highs, mediums, and lows.

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THE DEVELOPMENT OF QUANTITY

Quantity as the simplest of qualities of an object is followed by more precise conservations of weight and volume which can all be measured with numeric units.[11]

Quantity is simply the amount of material--more, less, or the same amount--without regard to its weight, volume, or mass. Just as with every other concept, quantity is conceptualized by both a classification and seriation system which organize part/whole operations and ordered differences of quantity. Since it is a specific quality or concept, quantity is only found when specifically addressed in science materials. It is not mentioned in either the mathematics or science *Common Curriculum Gaols*.

Except for the concept of object identity itself, quantity is the most basic of qualities of objects. It is even more general than number or measurement, and includes them as special cases. It develops before weight, volume, and all other qualities susceptible of measurement. The OCATS Developmental Assessment Project showed surprisingly low developments at all grade levels except perhaps third. Again, none of the grade level samples showed a consistent understanding of quantity in spite of its extreme simplicity as a concept.

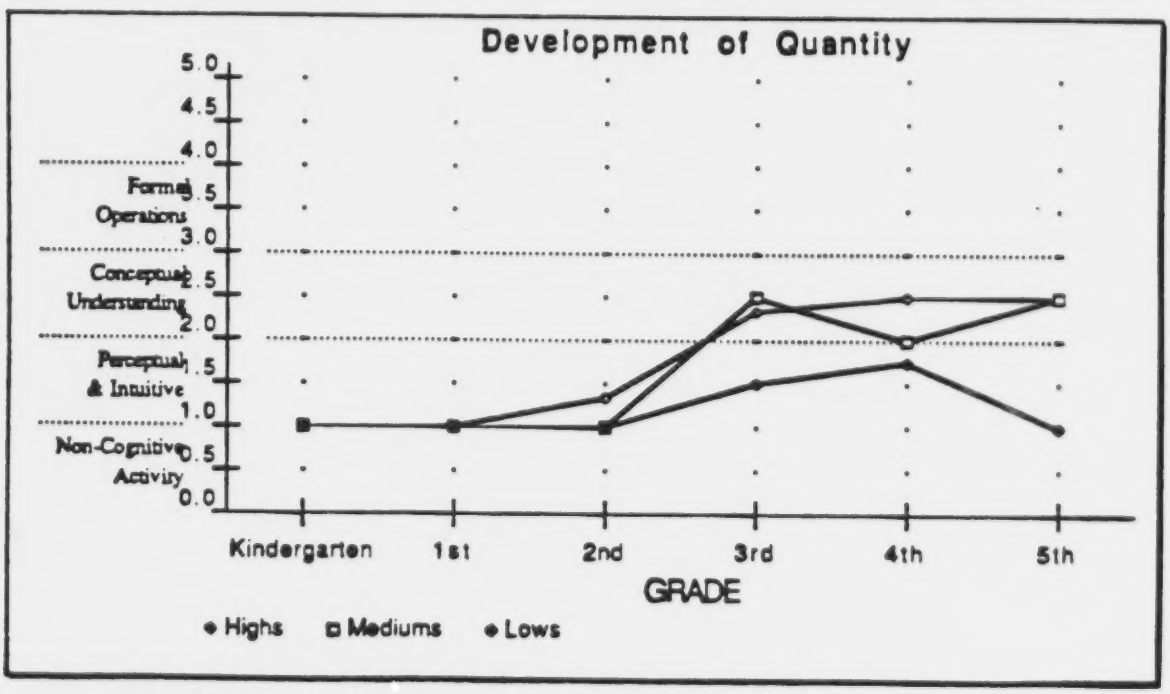

Figure 5 : The level of students' understanding of seriation from kindergarten to grade five.

THE DEVELOPMENT OF WEIGHT

The mental operations forming the concept of weight and later the formation of its unit of measurement do not develop out of the application of number to weight nor out of some generic measurement skill.[12] The understanding and eventual metrical measurement of weight develop independently out of earlier undifferentiated notions of the 'bigness' of objects, not number. This is true for all other physical qualities or properties as well. Just as with number, the formation of a unit of measurement of weight forms out of the coordination of part and whole operations (classification) and ordered differences (seriation).

Weight is addressed in the Mathematics CCG 5.2 and in the Science CCG 1.13 and 2.3.

Weight follows and depends on quantity in its development. As such, its development occurs later than quantity and the other first conceptualizations of classification, seriation, and number. In the OCATS Developmental Assessment Project, weight remained undeveloped in almost all of the whole school sample. Only the highs of grade four had put together a completed Stage IIB understanding of weight.

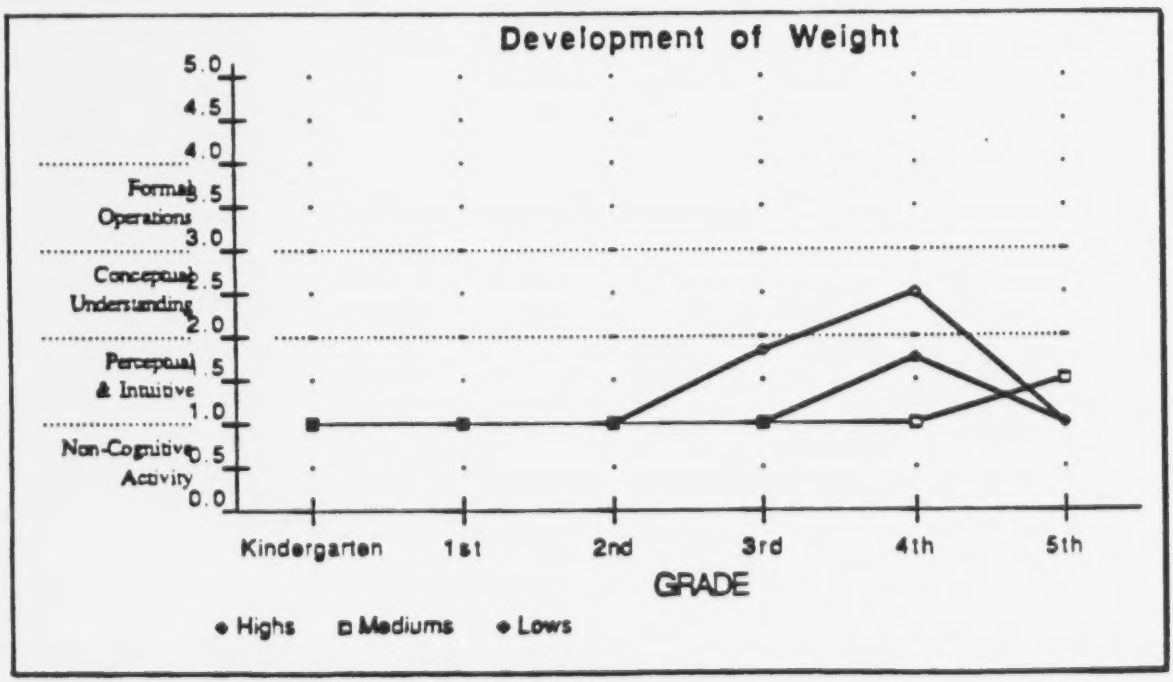

Figure 6 : The level of students' understanding of weight from kindergarten to grade five.

THE DEVELOPMENT OF VOLUME

Volume involves the coordination of three dimensions to 'unitize' space into a concept of volume.[13] Students construct two distinct conceptions of volume. The first concept of volume of Stage II is based on a no-

tion of what is contained by surfaces and is little more than the conservation of quantity. At Stage III, students understand that volume is not merely the interior 'contained' which is invariant but is part of space in a wider context. This extensive conception of volume is that of volume as a part of space as a continuum or 'container' taken as a whole. Rather than a content, 'Volume' is now one part of space as a continuum. The idea of space as a continuous whole is what allows the conservation of volume through perceived changes in the shape of an object. Only with the idea of space as a continuum does the student develop metrical units of space as a triple product of three dimensions.

Volume follows the development of weight and does not occur until around fifth grade. In the OCATS Developmental Assessment Project, only one student each at third, fourth, and fifth grades had put together a concept of volume (Stage III).

Volume as a physical property (which none-the-less requires formal operational thought for its understanding) is a concept usually specifically identified and addressed in science materials. It is named in the Science CCG 2.2 but could also underlie parts of CCG 2.1. Volume is identified in the Mathematics CCG 5.2.

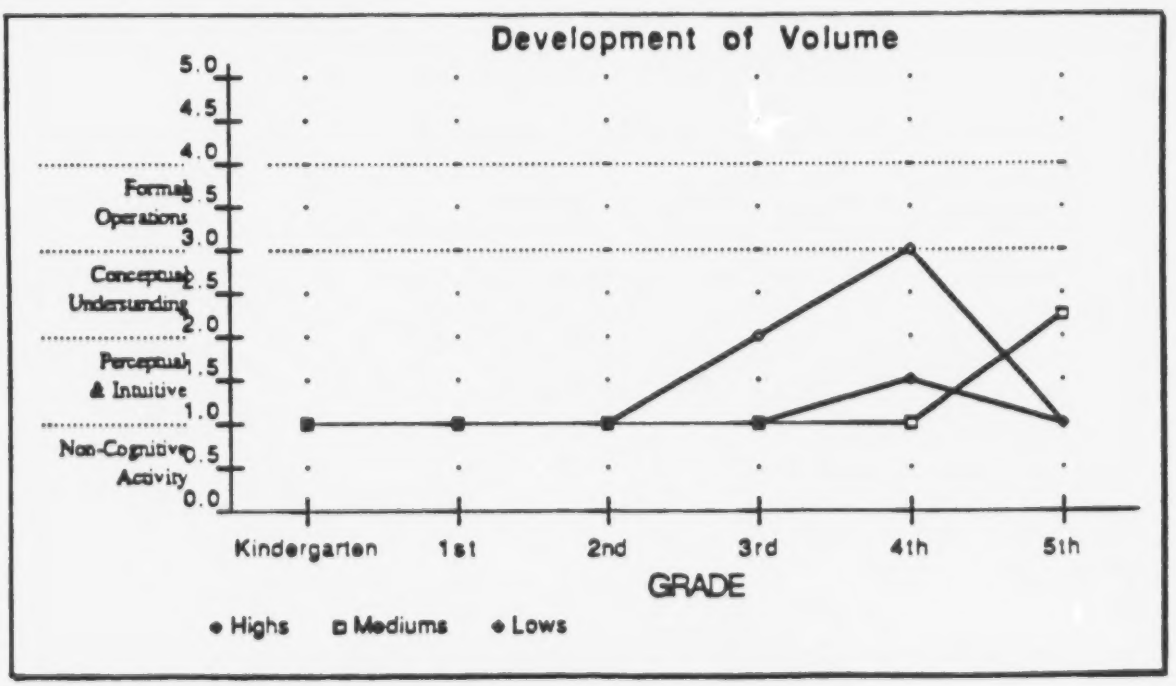

Figure 7: The level of students' understanding of volume from kindergarten to grade five.

THE DEVELOPMENT OF PERIMETER

The concept of length is found coupled up with spatial orientation to produce height, altitude, etc. Perimeter refers to the total length around an object. The development of understanding of length begins as a perceptual notion with judgement focusing on the endpoint or point of arrival.[14] At Stage II, the conservation of length emerges and the identity of an object with itself, such as a length of string, is asserted as the reason for the

constancy of its length through changes in its layout ("it's the same string"). But this identity itself depends on operational understanding that the total of different subdivisions is always equal to an invariant total.

Perimeter, or length, as a spatial concept describing objects, is a Euclidean concept (it eventually develops into a measured form). Prior, topological concepts, such as enclosure (surrounding), proximity (closeness), intersection (touching), and order (in front of, behind, beside but not right or left) are first developed to understand and describe space. Perimeter follows somewhat later the development of the first topological concepts, and the the OCATS Developmental Assessment Project sample reflects this lag. Except for the fourth grade highs, the understanding of perimeter gave students at all grade levels some difficulty. It appeared in completed form consistently in the third, fourth, and fifth grade highs.

Length as a fundamental spatial concept is necessary for the construction of a scientific description of objects and would be one of a large number of concepts subsumed under the extremely general Science CCG 2.4. Euclidean concepts are more specifically identified in the Mathematics CCG 4.3

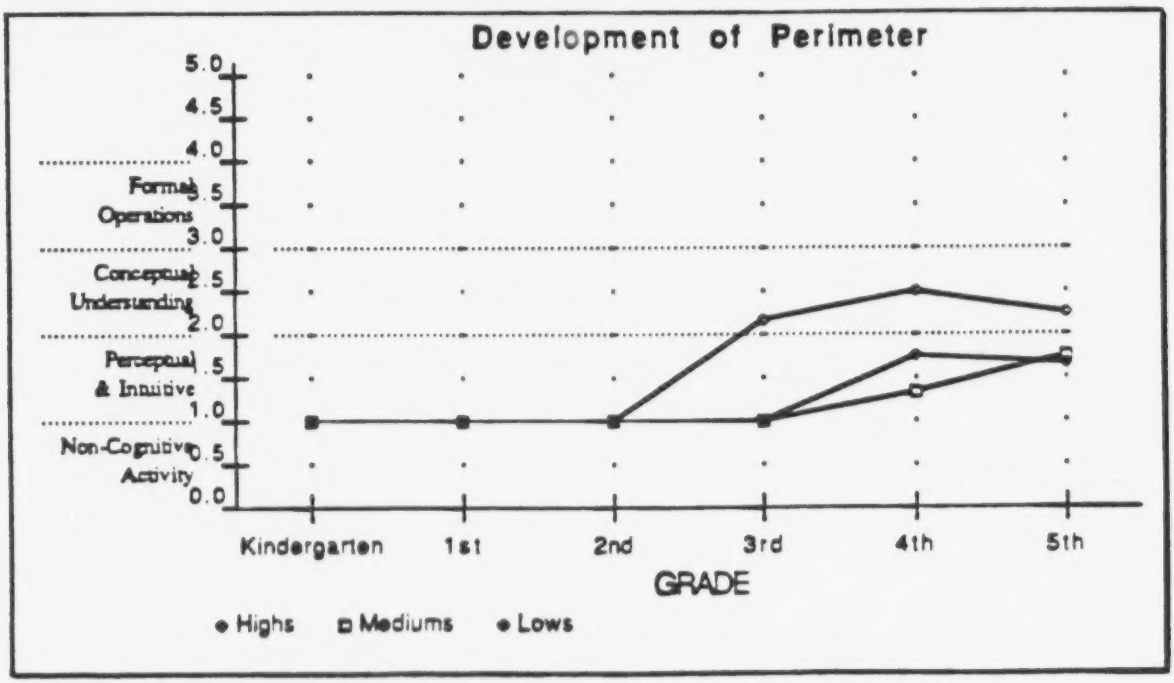

Figure 8: The level of students' understanding of perimeter from kindergarten to grade five.

THE DEVELOPMENT OF AREA

Length, area, and volume are closely related as purely geometrical concepts but as mental constructions, each raises its own distinct problems. This is particularly evident in volume which requires formal operations for its understanding. Area is another Euclidean concept necessary to the physical description of objects, and it is understood in a qualitative but not metrical form at Stage II.[15] Just as with every other concept, the students' understanding must compose parts into invariant wholes so that any object conserves its dimensions when it undergoes a change of position.

For the concept of area, composition is a matter of grouping or addition of parts to form a whole, and conservation is simply the expression of the fact that the arrangement of parts does not affect their sum. Above all this composition leads to understanding that the spaces left free and those which are newly occupied mutually compensate one another. However, this conservation is still not metrical and measurement of area and understanding of areal units requires the formal operational thought of Stage III.

In the OCATS Developmental Assessment Project sample, just as with perimeter, area was understood generally only by the highs at third, fourth, and fifth grades.

As with all Euclidean concepts, area is appropriately identified under the science CCG 2.4 and is more specifically identified in the mathematics CCG 4.3, 5.2, and 5.3.

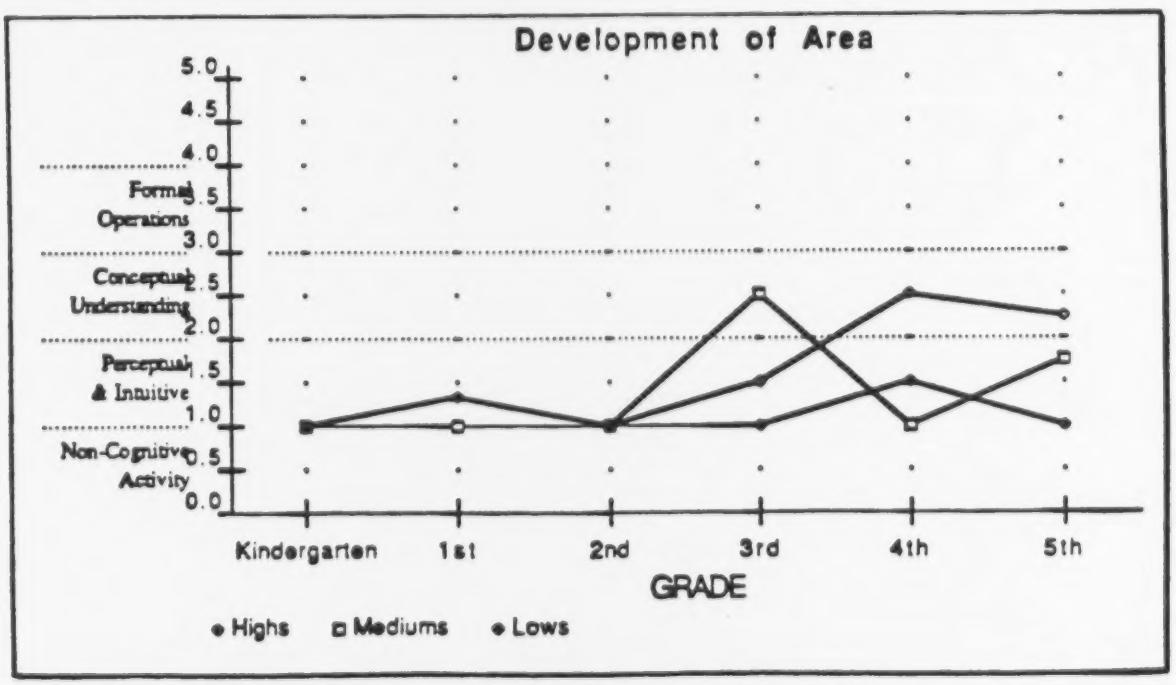

Figure 9: The level of students' understanding of area from kindergarten to grade five.

THE DEVELOPMENT OF MULTIPLICATIVE PROJECTIONS

Following the development of topological concepts which provide simple, qualitative spatial descriptions of individual objects are the projective concepts.[16] Parallel in development with Euclidean concepts, these projective concepts provide a system of spatial orientation among figures. With projective concepts objects can be related one to another to determine relative positions and definitions of shape, and orientation of figures relative to planes or viewpoints. Projective concepts account for the shapes of figures, their relative positions, and apparent distances in relation to a specific point of view. It is the development of a 'point of view' that transforms the students' topological conceptions of objects into projective ones. The two operations fundamental to projective geometry are projection and sectioning. The projective straight line is the fundamental concept since it organizes projective constructions and it is the only thing which remains unaltered in shape during projections and changes in viewpoint.

In the development of students', conception of space, topological concepts develop earlier than projective and Euclidean ones. The OCATS Developmental Assessment Project assessed the concept of point of view by having students draw how a tilting disk would appear from another point of view. The drawings students produce show how they logically multiply projective order relations to construct a point of view.[17]

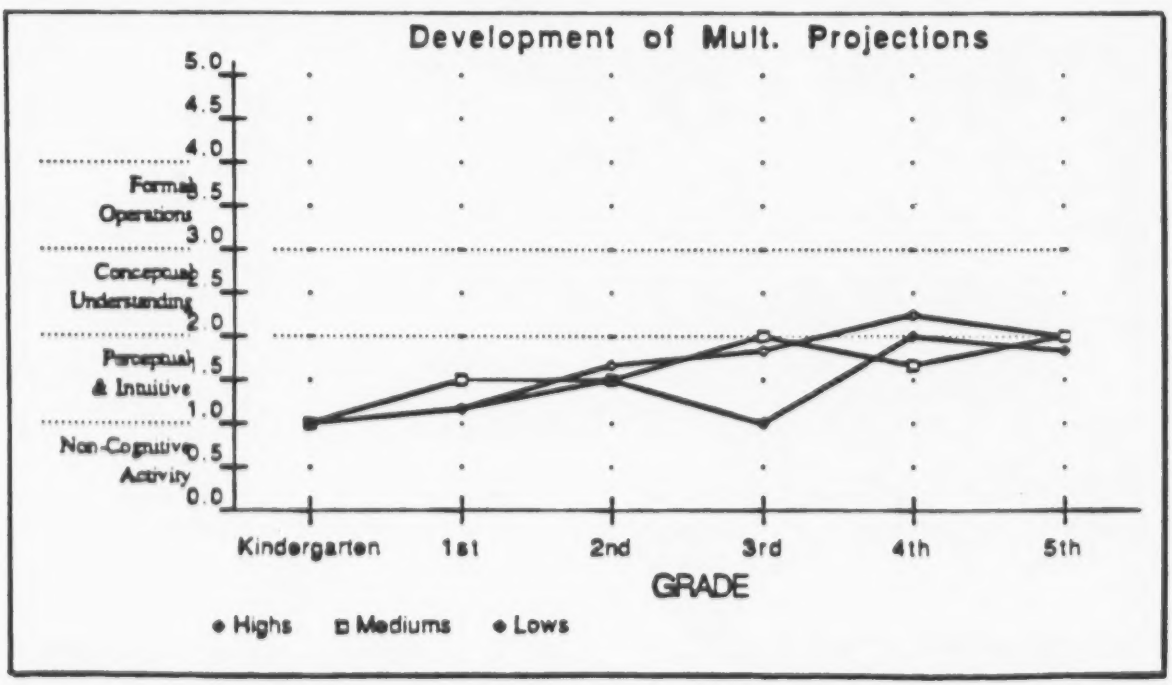

Figure 10: The level of students' understanding of multiplication of projections from kindergarten to grade five.

The development of this concept seemed slightly ahead of other concepts. Except for the third grade high achievers, most students in third, fourth, and fifth grades had partially or fully put together this spatial concept, and there were second grade students in the high, medium, and low achievement categories that also had partially completed this construction.

The science CCG 2.4 which is a general reference to spatial concepts would include projective relations. The mathematics CCG 4.1 and 4.2 address projective concepts.

THE DEVELOPMENT OF THE CONTROL OF VARIABLES

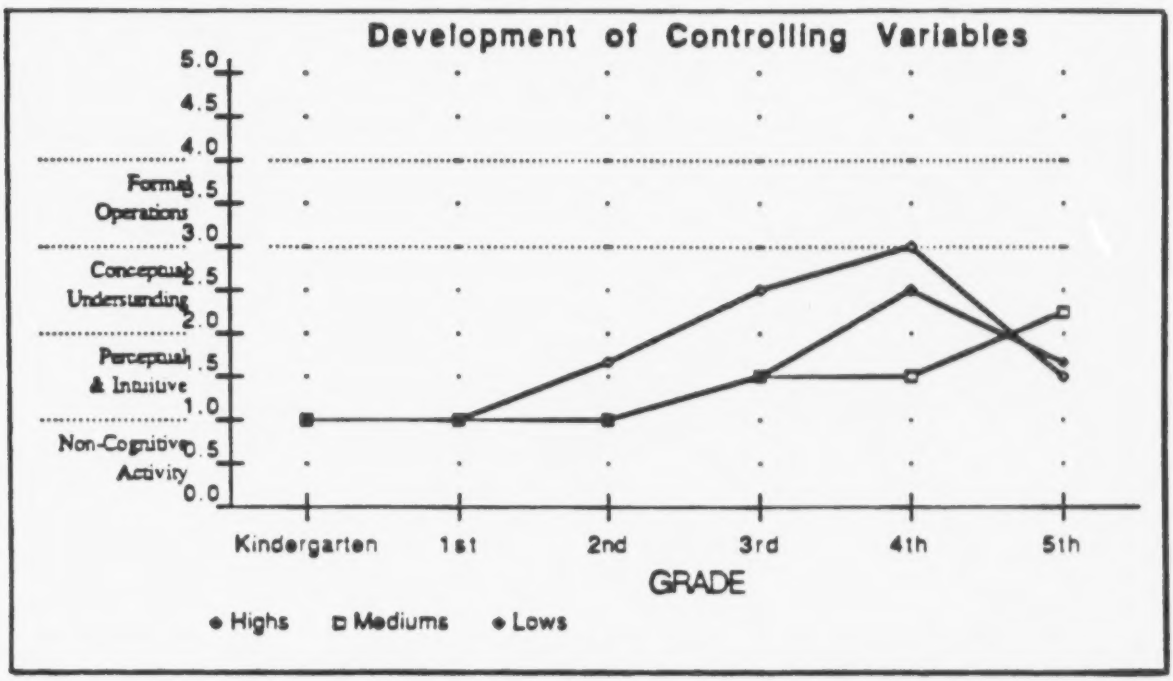

Figure 11: The level of students' understanding of controlling variables from kindergarten to grade five.

Separating out a variable is not the same as isolating a variable.[18] For example, if in studying the effects of weight, shape, material, size, and length in their possible effects on the bending of rods, all students can usually separate out and identify a variable and often even predict its effect on bending. However, only with the organizing logic of formal propositional operations can students isolate a specific variable to verify its precise effects by simultaneously controlling all other variables.[19]

The organizing power of propositional logic in the control of variables depends on a particular use of the combinatorial system inherent in propositional logic. The combinatorial system in propositional logic allows the student to generate the combination of variables necessary to experimentally verify the effect of a particular variable. Thus, the control of variables is one of several distinct operations used in experimental reasoning and made possible by propositional logic and its combinatorial structure.

The propositional logic of experimental reasoning first begins to appear around fifth grade. During the elementary grades, students are developing the observational procedures of concrete descriptions and cannot as yet turn concepts into variables, i.e., propositions. Thus, el-

ementary students can think conceptually to determine whether there are more cows or more animals but cannot reason about these classes to determine whether there are more that are not cows or more that are not animals, a problem solved only by formal operations. That is why elementary student cannot successfully perform the reasoning involved in true experiments.

In the OCATS Developmental Assessment Project no fifth graders, but some of the high third and fourth graders had begun to develop the isolation and control of variables.

Controlling variables in experimental reasoning is clearly identified in the science CCG 2.10, 2.11 and in a general way in 1.22, 2.12.

THE DEVELOPMENT OF PROPORTIONAL EXPLANATION

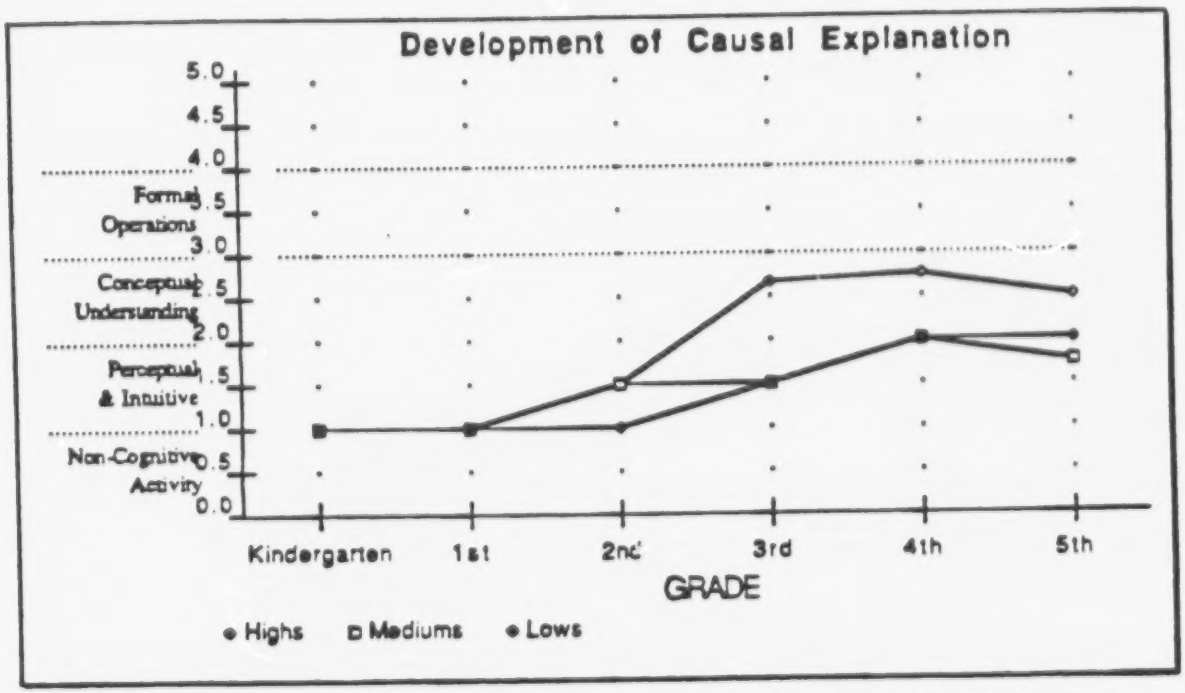

Figure 12: The level of students' understanding of causal explanation using proportionality from kindergarten to grade five.

The formal operation in the previous case was the control of variables and it relied on the use of particular formal operations of propositional logic. There are many other forms of formal logic such as most instances of causal explanation. Explanations involving proportionality, such as explaining the inverse relationship of distance and size in producing shadows are an example.[20] Proportionality is one method of explaining equilibrium conditions. As such, proportional reasoning clearly displays the formal operational thought involved in understanding direct proportional relations (as in the case of distance and size in maintaining a constant shadow) or inverse relations (as in the case of weight and length in maintaining the equilibrium of a balance beam).

The development of proportional reasoning in explaining the projection of shadows depends first on Stage II conceptualizations of the variables, lengths or distances, sizes, angles, projections, and sections (the ob-

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jects blocking the light and the image on the screen). Next in development comes the qualitative form or understanding of proportions followed by a quantified form expressed in a formula at Stage IIIB. In the OCATS Developmental Assessment Project sample, no students had as yet constructed an initial, qualitative understanding of proportional understanding of Stage IIIA.

Proportions are one example of many forms of causal explanation. To causally explain means to formulate a model of the interactions among various factors which show how objects act on one another to produce changes. Attributing a proportional model of explanation to the projection of shadows, balance beams, the equilibrium of gas conditions, and so forth all would be specific capabilities under the science CCG's 1.1, 1.2, 1.11, 1.15, 1.17, 1.18, 1.19, 2.9, and 2.14.

Conclusions

Assuming the sample is representative of the various grade levels, the the OCATS Developmental Assessment Project suggests these conclusions:

1. It appears that before third grade students do not have any of the basic science concepts which are necessary to successful learning.

2. At fifth grade, many students have not yet constructed some of the basic science concepts (those completed at Stage II) such as the qualities of weight, the spatial concepts such as simple projective (point of view, sectioning) and Euclidean (length, perimeter, area) concepts.

3. Almost no students are ready to address formal concepts (those completed at Stage III) such as volume, experimental reasoning, and proportional models of explanation.

4. Even the simplest of concepts (classification, seriation, multiplicative classification, and number) are weak at the fourth and fifth grades.

5. It appears that spatial relationships might be one of the strengths of the sample.

6. Multiplicative systems (matrices, double systems of description) appear particularly slow in developing.

7. The concept of number lags surprisingly at the fifth grade.

8. The third grade sample was advanced in comparison to the fourth and fifth grades. Either the third grade sample is unusual in some way or development significantly slows down after third grade.

Research on the development of knowledge in students has established an important fact. Every instance of students' learning depends on the prior development of a capability without which a student cannot derive long terem benefit from educational activity.

In the Concept/Process-Based Science Project school sample, the development of students' capabilities begins in first grade with preliminary constructions of simple, descriptive concepts. At this level, students are constructing basic physical concepts which describe concrete qualities of objects; spatial concepts which describe forms and shapes; logical concepts which organize objects by similarities, differences, and number; and time relationships which locate the duration and order of events in relation of one to another. These notions are not yet completely formed in thought as concepts and remain tied to actual activity with objects such as sorting, placing, arranging, corresponding, and so forth.

From kindergarten through the 2nd grades knowledge in students is only pre-conceptual and its intuitions are unstable. Students' thought is not rational and cannot yet form stable, logical concepts nor does it easily represent qualities of objects in their absence. The notions these students use often distort, change, and confuse things. And without the direct availability of objects, their representations and memories of situations only provide them with fleeting and then often erroneous observa-

tions. The slightest perceptual difference in situations often leads to all kinds of difficulties in understanding whether and what has changed.

But by third grade, students have put together a conceptualization of the basic qualities describing objects, number, spatial characteristics and so forth. These initial constructions describing concrete reality are available to students as concepts which represent objects in a stable way in their absence. Such conceptualizations allow simple types of learning through verbal representations and the extension and generalization of these concepts to various situations and problems.

At fourth and fifth grades students generalize and extend the initial concepts and continue to construct additional concrete concepts. Two additional problems addressed in fourth and fifth grades are (1) the construction of measurable units out of the qualitative understanding of concepts previously formed and (2) the formation of relationships among concepts to form deductive systems and inter-relationships such as matrices, syllogisms, correspondences, correlations, and logical multiplications.

Apparently it is beyond fifth grade, at which students begin the construction of formal understanding. During this period students begin by turning descriptive concepts such as length, weight, and so forth into variables. These variables are then organized into explanatory models. For example, they compose *changes* in length with *changes* in weight to describe the equilibrium of a balance beam by means of a proportional model. This means the descriptive concepts are now *variables*, organized by the hypothetical deductive reasoning capability of formal operational thought.

IMPLICATIONS

Qualitative, developmental assessment allows a clear distinction to emerge between the development of students' understanding of a concept and the use of a concept in learning. This distinction between student development and student learning leads to several interesting and useful possibilities.

Learning activities, such as providing students with demonstrations or perceptual experiences that show the equality of two sets of counters, are not enough to allow understanding in students. Understanding equivalence when counters are re-arranged does not come from experiencing the objects or being shown. It comes from actively initiating and organizing for oneself the various relationships.

The assessments confirm that reality is not known by the students through their perceptions since their perceptions actually misled them; students perceived increases of quantity, number, weight, when there were none. Students' knowledge fundamentally depends on the developmental level of the system of understanding they have available by which to make sense of an experience.

Students do not remember what they do not understand, they do not objectively perceive what they do not understand, they do not hear what they do not understand, they do not attend well to what they cannot understand, and they are not interested in learning about what they do not understand. The development of understanding must come before learning since it depends upon it.

Some conclusions of developmental research are the following:

1. Developmental assessment has allowed us to see a fundamental difference between evaluating students' learning and students' development. And, this distinction holds great promise for making corresponding distinctions in methods of instruction or evaluation.

When students are developing an understanding, they shift among the different aspects they already know in order to 'put together' a coherent understanding. The problem is not to accumulate more facts but to fit things together. And once everything is fitted together into a rational conceptualization, even what is seen as fact may appear different. Learning, on the other hand, involves discrete accumulations, extensions, and applications without necessarily constructing new forms of concepts or methods of understanding. Thus, instruction can focus students activity either on learning or on development.

Likewise, evaluation can focus either on learning and achievement or on the development of understanding.

2. Students at all levels need developmental--not learning--activities prior to using concepts in learning.

Developmental activities are activities which allow and encourage students to initiate and organize their experiences so as to 'conceptualize' them. Development means the construction of an understanding and it is promoted by making students responsible for generating the methods, abstractions, and explanations of educational activity.

On the other hand, learning activities, which use already formed concepts, allow students to take in information or make applications of concepts to problems. Without the concepts having been already constructed which allow understanding, learning activities will probably be of little value in promoting significant growth of most of the students.

Only some students at the third grades can as yet meaningfully and rationally learn from or represent their understanding in verbal activities. To understand and then to learn should be the order of educational activities.

3. It appears important to distinguish the learning activities from the concepts which are to be developed and are necessary to understand the activities.

Students cannot study completed concepts directly. They can only understand educational activity with the kind of conceptualizations they have thus far constructed. If the learning activity pre-supposes the use of completed concepts, students have no access to methods for putting together the concepts. Learning activities must be distinguished from the concepts themselves.

4. If some students lack success on the Science CCG's it may be due either to a learning problem or a development problem.

Students may not be able to coordinate a system of mental activity necessary to form an understanding of a concept in which case the problem for the student is developmental. For example, students may not understand units of length and activities teaching them how to measure if the concept of length has not been constructed.

On the other hand, students may have the capability to understand but may lack adequate language, interest, or experience. In which case, students simply may not have attended to learning the information. Distinguishing the two problems is important for diagnosing lack of progress.

5. It appears that methods and materials which clearly display students understanding and help develop those understandings are essential to science instruction.

Instructional materials almost always organize and explain everything to students when organizing and explaining should form the heart of the students' role. At the third grade, the range of differences among students' conceptualizations is at least five years. It is impossible to find a single point of development to which instruction can be geared. The solution lies in opening up the range of accommodation of instruction to developmental differences by allowing students to organize their activities.

6. Underlying all other implications, developmental research suggests the importance and promise of widening educational methods from a singular focus on observable performance and learning of correct responses to including methods which work with the development of the mental activity of students.

End Notes

[1] See the various science curriculum papers published by the Oregon Department of Education for descriptions of concept/process based science education.

[2] Jean Piaget, *Logic and Psychology*, trans. Wolfe Mays and Frederick Whitehead (New York: Basic Books, 1957), pp. xvii-xix, 23-26.

[3] For a summary of qualitative methods and their findings, see Jean Piaget and Bärbel Inhelder, "Intellectual Operations and their Development." In *Experimental Psychology: Its Scope and Method*, 9 vols. Paul Fraisse and Jean Piaget, gen. eds., (New York: Basic Books, 1968-1970), vol. 7: *Intelligence*, by Pierre Oléron, Jean Piaget, Bärbel Inhelder, and Pierre Gréco, trans. Thérèse Surridge (1969), chapter 24.

[4] Ibid.

[5] Jean Piaget. "The theory of stages in cognitive development." In D.R. Green; M.P. Ford; and G.B. Flamer (eds.), *Measurement and Piaget*, (pp.1-11). McGraw-Hill, Inc., 1971.

[6] See the research cited in the following sections for complete information. Piaget and Inhelder's "Intellectual Operations and their Development", pp. 155-178 provides an overview of various developments.

[7] Bärbel Inhelder and Jean Piaget, *Early Growth of Logic in the Child: Classification and Seriation*, trans. Eric A. Lunzer and D. Papert (New York: Harper & Row, 1964), pp. 7-20, 47-48.

[8] Ibid, pp. 151-154.

[9] Ibid, ch. 9.

[10] Jean Piaget and Alina Szeminska, *The Child's Conception of Number*, trans. Caleb Gattegno and Frances Mary Hodgson (London, Routledge and Kegan Paul, 1952), ch. 6, pp. 177-184.

[11] Jean Piaget and Bärbel Inhelder, *The Child's Construction of Quantities*, trans. Arnold J. Pomerans (Basic Books, 1974), pp. vii-viii, ch 1.

[12] Ibid, ch. 2, 9, 10, 11.

[13] Ibid, ch. 3, 12; and Jean Piaget, Bärbel Inhelder, and Alina Szeminska, *The Child's Conception of Geometry*, trans. E.A. Lunzer (Basic Books, 1960), ch. 13, 14.

[14] Ibid, ch. 4-8.

[15] Ibid, ch. 11-13.

[16] Jean Piaget and Bärbel Inhelder, *The Child's Conception of Space*, trans. F.J. Langdon and J.L. Lunzer (W.W. Norton, 1967), ch. 15.

[17] Ibid, ch. 6.

[18] Bärbel Inhelder and Jean Piaget, *Growth of Logical Thinking From Childhood To Adolescence: An Essay on the Construction of Formal Operational Structures*, trans. Anne Parsons and Stanley Milgram (Basic Books, 1958), p. 284.

[19] Ibid, ch 3.

[20] Ibid, ch. 13.

STDNT Ach	Cls	M Cls	Ser	Nbr	Ontv	Wght	Vol	Per	Area	M Pri	C Var	P Exp
GRADE 3												
3AH1	2.5	2.5	2.5	2	2	1	1	2	1	1.5	2	2
3KH5	3.5	2.5	2.5	2.5	2.5	2.5	3	2.5	2.5	1.5	3	3.5
3BH2	2	2.5	2.5	2.5	2.5	2	0	2	1	2.5	2.5	2.5
3 Highs	2.7	2.5	2.5	2.3	2.3	1.83	1.3	2.17	1.5	1.83	2.5	2.67
3EM2	2.5	2.5	2.5	1	2.5	1	1	1	2.5	2	1.5	1.5
3 Mediums	2.5	2.5	2.5	1	2.5	1	1	1	2.5	2	1.5	1.5
3JM5	2.5	2	2.5	2.5	1	1	1	1	1	0	0	0
3HL3	2.5	2.5	2.5	2.5	2	1	1	1	1	1	1.5	1.5
3 Lows	2.5	2.25	2.5	2.5	1.5	1	1	1	1	0.5	0.75	0.75
GRADE 4												
4AH5	2.5	2.5	2.5	2.5	2.5	2.5	3	2.5	2.5	2.5	3	2.75
4EH1	3	2.75	2.5	2.5	2.5	2.5	0	2.5	2.5	2	0	0
4 Highs	2.75	2.625	2.5	2.5	2.5	2.5	1.5	2.5	2.5	2.25	1.5	1.375
4FM2	2.5	2	1	2	2	1	1	2	1	2	1.5	2
4BM1	1.5	1.5	2	2	2	1	1	1	1	2	1.5	0
4IM1	2.5	1.5	2	2	2	1	1	1	1	1	1.5	2
4 Mediums	2.17	1.7	1.7	2	2	1	1	1.3	1	1.7	1.5	1.3
4CL5	1.5	2.5	2	2.5	1	1	1	1	1	2	0	1.5
4JL5	2.5	2.75	2.5	2	2.5	2.5	2	2.5	2	2	2.5	2.5
4 Lows	2	2.625	2.25	2.25	1.75	1.75	1.5	1.75	1.5	2	1.25	2
GRADE 5												
5BH4	2.5	2.5	2.5	2.5	2.5	1	1	2	2	2.5	1.5	2.5
5CH2	3	2.5	2.5	2	2.5	1	1	2.5	2.5	1.5	0	0
5 Highs	2.75	2.5	2.5	2.25	2.5	1	1	2.25	2.25	2	0.75	1.25
5AM5	2.5	2.5	2.5	2.5	2.5	2	3.5	2.5	2.5	2	2.5	1.5
5FM3	1.5	2.5	2	2.5	2.5	1	1	1	1	2	2	2
5 Mediums	2	2.5	2.25	2.5	2.5	1.5	2.25	1.75	1.75	2	2.25	1.75
5EL3	2	1.5	2	2	1	1	1	2	1	2	1	2
5HL3	2	1	1.5	1	1	1	1	1	1	2	2	0
5IL3	2.5	1	2.5	2	1	1	1	2	1	1.5	2	0
5 Lows	2.17	1.17	2	1.67	1	1	1	1.7	1	1.83	1.7	0.67

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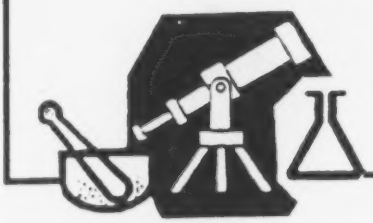

Concept/Process-Based Science

Science Curriculum Concept Paper #4

By Richard Meinhard, PhD.

I. Introduction

Major efforts are underway to identify and define a science of science education which will reverse the relationship between research and program development (Resnick, 1986; Shulman, 1987). This trend is toward using research on how learners grow and develop *prior* to program development and the organization of instructional techniques. The trend is a movement away from basing programs on a pre-established philosophy or using research techniques merely to test for program effects *after* a program has been formulated. Clear scientific explanations of how students learn will be of great practical value in assisting teachers to more directly work with and promote students' learning activities. It is the advancement of scientific understanding which informs, makes possible, and, in general, promotes humans' practical activity. Therefore, in order to define concept/process-based science education, this paper begins by summarizing the relevant research trends.

The research which leads to a definition of concept/process-based science can be summarized in four, main areas which suggest and substantiate qualitative changes for Oregon science education. These include:

- the instructional methods teachers use,
- the curriculum that is identified as important to student growth,
- the learning activities in which students are asked to participate,
- and the evaluation of student growth.

An additional, fifth component also provides guiding principles for concept/process-based science and particularly Science, Technology, and Society education (STS):

- placing science in a broader, interdisciplinary context which relates it to societal values.

II. Trends from Research

While individual research findings do not directly tell educators what to do, trends in research have important implications for educational practice. Increasingly, these trends are toward:

- explaining how knowledge is not transmitted but develops as a human mental activity,
- showing how concepts and scientific knowledge can be described and specified,
- describing the students' constructive activities of conceptualization,
- explaining how students' systems of mental activity or 'naïve conceptions' reorganize themselves as students' use them and develop an understanding of a concept—in other words, explaining the stages of conceptualization, and
- understanding science as playing a necessary and valuable role in illuminating practical problems of human adaptation to the world and not just as a body of knowledge studied for its own sake.

The research trends, indicating that researchers are reorganizing their fundamental conceptions of how students learn science, are producing qualitative changes in science education (NSTA, 1987; Linn, 1987; NASBE, 1988; and see Shymansky and Kyle, 1988; and the Blosser and Helgeson series of summaries). The awareness of these qualitative changes clarify how concept/

process-based science programs differ from traditional science programs in each of the five areas discussed above. From these differences comes emerging responsibilities and directions for change by support personnel and science teachers.

Each of the following sections discusses the research trends by (1) posing a fundamental problem of science education, (2) discussing a trend emerging from advances in research, and (3) drawing the implications from the scientific basis for concept/process-based science. Each ends with a summary chart.

1. Instructional Methods

Problem: In attempting to educationally promote the development of scientific knowledge in students, can knowledge be *directly presented and transmitted to students* such as through language or in experience with objects? Or, is knowledge *an internal or mental, constructive activity* which is simply stimulated and triggered by external sources such as teaching? Is it possible to have the learner directly study completed knowledge? Or, can instruction only assist the learner in putting together knowledge such as through problem solving cycles?

The Trend: Instructional methods have primarily been based on perceptions, typologies, and procedural guidelines such as *Models of Teaching* (Joyce & Weil, 1986) or ITIP (Hunter & Russell, 1981). These methods usually have the intent of carefully organizing and directly presenting or demonstrating completed concepts to students for them to learn. Increasingly, however, instructional methods are being derived from research into the problem solving cycles and natural processes students must go through in the construction of concepts and understanding (Cate & Grzybowski, 1987; Pizzini, Shepardson, & Abell, 1989; Lockhead and Clement, 1979; Renner and Marek, 1988).

- The trend is toward basing instruction on methods which work directly with the dynamic constructive and problem-solving activities of the learner rather than on static models of presenting or showing completed concepts, and teacher organized learning activities and 'labs'.

Implication for Science Education: Rather than using the activity of students to practice or apply knowledge, the trend is toward assisting them to construct knowledge through the the activity itself. This means that rather than simply presenting and covering the material to be learned, instructional methods are being based on learning cycles which follow and facilitate the developing mental abilities of the student.

As the constructive nature of students' mental and physical activities is better understood, instruction will increasingly focus on first, helping students to generate concrete or practical activities and second, helping them abstract and conceptualize the concepts within the activities. These instructional cycles eventually and naturally lead the student to the abstract representations of concepts (such as mathematical and scientific formulas). Instruction, then, helps the learner reconstruct or 'conceptualize' previous mental and physical activity first using verbal and then mathematical forms. Commonly, these final, abstract formulas are the place where instruction begins. (See Chart I.)

2. Curriculum

Problem: In specifying what is to be developed in the learner, should knowledge be considered as *a body of information* to which increasingly complex information is added (that is, something which can be comprehended directly in completed form and which exists outside of the learner)? Or, should knowledge be considered fundamentally as *systems of mental activity* necessarily organized and initiated by the learner? In other words, should the curriculum specify knowledge as something to be presented ready made to the learner in static, completed form? Or, should curriculum essentially be viewed as an activity by the learner?

Chart I: Instructional Methods

A Traditional Science Program	A Concept/Process-Based Science Program
• Features clear organization and presentation of information either from teacher or text, or uses objects to show information (teacher centered). • Puts activity of learner after teaching and uses it to reinforce, apply, or practice what has been learned from teacher or text. • Features emphasis on testing of learner to insure control of learning through correct reception and recall. • Confuses method with how to present or expose knowledge to learner. • Assumes all learners 'ready' at same time.	• Features clear problem posing as initial beginning of activity with objects. • Makes organization and conceptualization of knowledge the responsibility of learner. • Works with and through learners' activities. • Is based on shifting learner activities through problem posing and solving cycles which follow natural construction and stages of conceptualization. • Constantly attempts to 'decontrol' learner to push learner toward independence. • Accommodates wide range of learners.

And, is that activity essentially a mental one or an observable, behavioral one?

The Trend: In a "call for fundamental reform" of the curriculum, the National Association of State Boards of Education (NASBE, 1988) called for K-12 curricula which address central concepts and thinking skills. These objectives address the need to develop fundamental intellectual capabilities which lead to understanding rather than superficial knowledge that covers many topics and is easily testable. Theodore Sizer's Coalition of Essential Schools features essential, intellectual capabilities by stressing that "less is more" (Wiggins, 1987).

Curriculum reformers (but not most teachers and publishers) are moving away from specification of a number of courses, coverage of texts, or hours of science instruction, to identification of fundamental concepts and understandings (e.g., AAAS, 1989), deeper mental processes of reasoning, investigation, and problem solving (Costa, 1985; Chi, Geltovitch, & Glaser, 1980), identification of the relations among concepts, and specification of the development of concepts (Lawson, 1988; Driver and Easley, 1978).

Rather than speculation and armchair task analysis of concepts, the mental complexity of the construction of understanding of various scientific concepts is increasingly being derived from research (Gardner, 1985) such as that reported in the *Proceedings of the 2nd International Seminar: Misconceptions and Educational Strategies* (Novak, 1987) and *Published Articles in Science Education: Alternative Conceptions and Cognitive Development* (Dykstra & Schroeder, 1987).

Chart II: Curriculum

A Traditional Science Program	A Concept/Process-Based Science Program
• Tends to be based on topics, information to be covered, or written materials to be used. • Has fragmented notion of educational objectives, often a listing of skills and content. • Specifies knowledge specified as behaviors, performances, or uses. • Based on static 'body' of information which can be transmitted and learned; division into content and process skills.	• Abstracts and identifies important capabilities or systems of understanding making up an area of study. • Concepts and processes seen as two integrated aspects of any understanding. • Focuses on mental rather than observable activity. • Based on knowledge not static body but internal activities which depend on what and how learner initiates and organizes.

These research findings are the beginnings of a scientific basis for specification of the science curriculum.

- The trend is to see and define the concepts of the science curriculum as mental *activities* whose *development* forms different perspectives and misconceptions leading up to the most current valid scientific conceptions. The trend is away from seeing the science curriculum as a static content or a body of knowledge to be covered.

Implication for Science Education: The trend to understand knowledge as mental activity means to understand: (1) concepts as organized systems of thought and not as simple accumulations of learning, (2) knowledge as *mental* activity and not as behavioral activity or as specific performances, and (3) concept development as the formation of perspectives, wholes, or *systems*, and not merely as the accumulation of facts and isolated experiences. (See Chart II.)

Once these underlying systems of thought are better understood and their stability and shaping influence is studied (as Piaget and others have already done with many scientific concepts), they will become increasingly important as teachers use them to develop scientific competence in their students.

3. Learning Activities

Problem: Is learning a *reception of information* which the learner must then understand through activity such as practice or application? Or, is learning essentially *mental activity initiated and organized by the learner* which shapes what the learner sees and experiences? Can a learning

experience be presented to the learner? Or, must it be constructed by the learner? The problem rests in whether the learner's activity is thought to be formative of knowledge and the source of understanding or whether the learner's activities are merely products or outputs used to receive, practice, store, and display something delivered by instruction.

The Trend: Science education research is moving toward identifying the essential importance of the learner's activity and involvement in putting together scientific knowledge (Bredderman, 1983; Shymansky, Kyle, and Alport, 1983). Intimately bound up with the increasing emphasis on constructive learning activities are active interpersonal exchanges among students in cooperative learning (Johnson & Johnson, 1986; Slavin, 1988). Essential to the notion of active learning is the principle that this student activity is directed to objects and not to abstract verbal concepts and processes. Student organized activity always provides the necessary and essential beginning point for students' mental constructions. Active learning does not mean the use of manipulatives to present information or to have learners practice presented information.

- The trend is toward seeing learning as an activity organized by the student and directed to the world (that is, an active assimilation of objects and phenomena), rather than as a passive, verbal reception from teacher or text, or as a passive recording of experience.

Implication for Science Education: The trend is to see learners as actively involved in construct-

Chart III: Learning Activities

A Traditional Science Program	A Concept/Process-Based Science Program
• Consists of application or practice of previously presented material.	• Uses and develops students' conceptual framework rather than "correct," completed understanding.
• Is preorganized by the teacher or text ('canned' labs, filling in tables or graphs, worksheets, etc.)	• Builds and reorganizes by examining previous learning and conceptual framework of students.
• Features premature 'closure', fragmentation, and topic hopping rather than building on previous learning.	• Shifts between learners' conceptual framework (logic) and testing it on real objects (experience).
• Directs learners' attention to completed knowledge to be learned rather than on objects, or activities are done for activities sake.	• Focus students' activities on objects to be understood rather than on already formed knowledge.
• Uses passive textbook-based survey type learning with interactions featuring short 'right answer' responses.	• Integrates experiential/lab activity with learners' organization of activity and data organization (table, graph, etc.).

ing their experiences rather than as passive receivers of information and experience who only act after the fact to make sense out of a received experience. The activity initiated and organized by the learner is therefore increasingly coming to be understood as the fundamental constructive factor in students' understanding of the world. Process and content are not two distinct things but simply the two aspects (logic and experience) which make up every instance of thought and knowledge. (See Chart III.)

4. Assessment of Student Growth

Problem: In understanding learner growth, should learning be considered as providing the development in the learner? Or, does learning depend on development which provides the capabilities to learn? In describing the growth of knowledge in students, is quantitative measurement of learned performances most important and objective? Or, is the growth of the learner more objectively described by qualitative measurements of specific mental abilities which themselves provide the conceptualizations necessary for learning and performance?

The Trend: The scientific study of learning is slowly discarding the old model of learning as an effect of a treatment (instruction) measured by achievement and performance tests. The trend is toward identifying the exact series of conceptual frameworks the learner goes through in constructing various scientific concepts (Driver & Easley, 1978; Gentner and Gentner, 1983; for examples see Mestre & Touger, 1989, and McDermott, 1984, for physics; Mintzes, 1984, for biology; Clement, 1983, for astronomy; Smith, 1989, for genetics).

Chart IV: Evaluation of Student Growth

A Traditional Science Program	A Concept/Process-Based Science Program
• Quantitatively measures sample of many learnings. • Focuses on right/wrong answers. • Sees growth as accumulation information from learning experiences. • Tests to determine retention, transfer, and application to problems of material previously taught. • Separates evaluation from learning and places it after learning.	• Qualitatively measures level of understanding of major idea using developmental stages. • Focuses on explanations and reasoning. • Sees growth as reorganization and extension of thought. • Uses assessment which triggers a display of current level of understanding. • Integrates evaluation with students' activities for constant self-regulation and redirection by learner.

Reporting learners' growth increasingly depends on tracing the development of these cognitive frameworks with the use of specific, qualitative stage scales which replace the quantitative measures of simple right/wrong performance (Ridgeway, 1988; Finley, 1986; Byron and Clement, 1980; Posner, 1982).

- The trend is toward measuring and explaining more fundamental aspects of learner growth by describing the qualitative development of underlying conceptual frameworks. The trend is to move away from quantitative measures and short term learning effects.

Implication for Science Education: Rather than a focus on observable performances as measures of learning, the trend is toward assessing the developments of the fundamental internal conceptual frameworks which produce the specific answers and performances of students. This trend of moving from assessing learning to assessing the development of understanding in learners means teachers will increasingly be asked to distinguish between short term learning effects and the long term development of understanding, and to shift from quantitative, single answer type tests to qualitative assessments of learning products such as portfolios and projects which provide displays of students' understanding.

5. Value of Science Education

Problem: Is science a unique field having its own intrinsic value? Or, does its role fundamentally grow out of human activity and human adaptation to reality? Is science a special domain with its own unique processes? Or, are there processes fundamental to human development which the scientist as well as young children employ? Do students study *about* the science which scientists do produce, or do students actually *do* science and derive its value implications?

The Trend: If science is a body of already completed knowledge which is studied by the student, then science exists in and of itself as a distinct subject having its own value. But scientific knowledge is increasingly seen to be fundamentally a constructive activity involving both the investigator's active mental construction and facts and experiences from external sources made possible by those constructions. Scientific knowledge is thus essentially an increasingly objective human activity.

STS (science, technology, and society) is the attempt to understand and make use of the fundamental utility of scientific investigation in human problem solving and adaptation (Bybee, 1986; Roy, 1985; Singleton, 1988).

- The trend is to see scientific understanding as the active and necessary solution of fundamental problems of human adaptation encountered in even the most mundane of projects, and not to view science as an end in itself whose esoteric intricacies are pursued only by advanced students.

Implication for Science Education: This trend is toward seeing problem solving and investigation as fundamentally a human processes. It suggests that science teachers will be increasingly asked to facilitate science understanding by basing students' science experiences on activities of practical scientific understanding and then extending them into human problems and implications (STS) rather than simply teaching science as a distinct body of knowledge produced by scientists.

Concept/process-based science attempts to recognize the trend to place the world in the hands of students and have them actively organize and study it rather than have it presented to them as a completed, static body of knowledge. The fundamental need and value of science grows out of directly confronting the real world in all its complexity, and the need to understand the world is raised by problems of human activity in the physical and living environment. (See Chart V.)

Chart V: Values in Science

A Traditional Science Program	A Concept/Process-Based ScienceProgram
Sees: • science as fun, isolated activities. • science important to taking next science course or getting high test scores. • science a body of valued information about the world which can be applied. • science distinct from 'practical', everyday activity. • science as isolated from the real, practical world.	**Sees:** • scientific investigation as interesting. • science as thoughtful investigation and understanding of the world. • science as awareness and thoughtful reflection of human activity directed to changing the world. • science as informing human activity and anticipating reasons for success or failure.

III. Definition of Oregon's Concept/ Process-Based Science

The movement toward a science of science education means educators must look deeply into their programs to determine what model of the learner their program is based on and whether that model is based on research or derived from personal opinion and preference. Concept/process-based science education is not a particular program but a general direction for continual program refinement and renewal. General trends from research lead to the five features defining Oregon's approach:

- Concept/process-based science education is the movement in science education toward **identifying and basing science education on those fundamental ideas necessary for students to objectively understand the world.** It is a movement away from topical or textbook-controlled coverage of information which lacks underlying, integrating goals of conceptual development.

- Concept/process-based science education is the movement toward instructional methods which are based on and follow **the constructive process of students' developing mental activity in putting together the fundamental ideas of science.** It is a movement away from teaching methods which are based on attempts to directly present or transmit completed concepts and understandings to students.

- Concept/process-based science education is the movement toward learning activities in which **students study real objects and phenomena so as to conceptualize them** by describing and classifying them, by seeing relationships in their changes, and finally, by providing explanations for causal changes. It is a move-

ment away from having students study completed science concepts and knowledge through careful, teacher-organized canned labs, learning experiences, or demonstrations.

- Concept/process-based science education is the movement toward **objectively describing and evaluating the degree of development and quality of students' understanding** as they construct scientific knowledge through the learning activities. It is a movement away from simple quantitative measures of right and wrong answers, increased testing to control the focus of students' learning, or closed book tests disconnected from the learning products students produce.

- Concept/process-based science education is the movement toward placing science instruction in **an interdisciplinary context which promotes the intellectual development of students and their responsible engagement in practical, societal values.** It is a movement away from compartmentalizing science as an end in itself or isolating it from important ethical responsibilities of citizenship and stewardship.

The general directions for program development defined by concept/process-based science education provides help to teachers and their colleagues so they may identify specific changes in local programs. Concept/process-based science education works through local processes of curriculum and instructional review to identify and promote changes in curriculum goals, and instructional methods. Thus, concept/process-based science education is not to be seen as a program but as the result of changed thinking regarding the role and responsibilities of science educators in understanding and promoting student growth.

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700 Pringle Parkway, SE
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September 1990

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The original draft of this free-lancepaper was prepared by a science education researcher. Educators who served as reactors or editors of this paper include: Candy Armstrong (Region 11 OCATS staff development specialist), Pat Blosser (Science Education, Ohio State University), Wallace Cassel (Region 7 OCATS staff development specialist), Marvin Druger (Biology and Science Education, Syracuse University), Jerry Fenton (Region 4 OCATS staff development specialist), Dorothy Gabel (Science Education, Indiana University), Dale Rosene (Science teacher, Marshall Middle School, Marshall, MI), Susan Smoyer (Project Manager, Science Curriculum and Assessment Project, Northwest Evaluation Association), Ardith Stensland (Region 1 OCATS, co-director), David Stronck (Science Education, California State University-Hayward).

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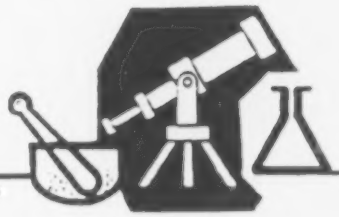
"Contributions of Piaget to Science Education"



SCIENCE CURRICULUM CONCEPT PAPER #2

By Richard Meinhard, PhD.

What Science Teachers Need to Know: Scientific Knowledge and Its Source

Like scientists, science educators need scientific knowledge regarding the objects and phenomena which are studied and understood in their disciplines. But science educators also need another science not needed by scientists. Science educators need scientific knowledge about *how students develop an understanding of scientific concepts* (Piaget, 1973b, pp. 21-23; 1970f, 166-173).

Educators' understanding of the development of scientific knowledge distinguishes science education as a profession and accounts for its very difficult nature. In short, science teachers must not only know scientific concepts; they must also understand how concepts develop in students' thought (Piaget, 1970f, pp. 123-133; 1973b, pp. 35-37).

There are three possible sources for concepts formed by human thought:

(a) concepts are formed and located outside the learner and are transmitted to the learner,

(b) concepts are hereditary intuitions and are expressions of innate capabilities to observe and generalize, or

(c) concepts are developed by constructive processes within the activity of the learner (Piaget, 1952, pp. 357-419; 1960, pp. 1-17; 1972, pp. 63-93).

Three Views. The three explanations of the source of students' knowledge lead to different educational practices:

(a) *External* -- If the source of scientific knowledge is thought to be *outside the learner*, then the teacher may become a giver of lectures, explainer, and organizer of demonstrations and hands-on experiences.

(b) *Internal* -- If the source of scientific knowledge is thought to be *inside the learner*, then the teacher may seek to use 'discovery methods' and draw upon the learner's innate capabilities or wait for them to develop.

(c) *Activity* -- If the source of scientific knowledge is thought to be in the *reorganization of activity to rebalance internal organizations with outside factors*, then the teacher may seek to work with students' mental activities, not simply performances, in order to develop the activities students attempt to initiate and adapt to reality (Piaget 1970f, pp. 25-29, pp. 137-180; 1973b, pp. 9-11, 92-109).

Piaget contributed a science of knowledge, genetic epistemology, which studies and explains the source of knowledge. Piaget's genetic epistemology focuses on the mechanisms which develop biological activity until it reaches the level of scientific thought. Genetic epistemology explains how human intelligence is a continuation of biological adaptation in which human activity makes contact with, and fits itself to, reality such that it comes to reflect reality in the precise manner of scientific knowledge (Piaget, 1960, pp. 14-17; 1970b, p. 12; 1972, pp. 19-20, 52-62).

Functions of Intelligence

In research on the development of knowledge, Piaget's scientific findings of genetic epistemology show that knowledge is not a state or a thing which is stored or transmitted. Knowledge is mental activity which actively organizes and acts on reality and thereby also fits itself to it. Mental activity arises out of the continuation of behavioral activity by reconstruction and conceptualization in systems of mental activities (Piaget, 1973a, pp. 49-61; 1971a, pp. 1-7).

> ***Piaget's contribution was to change knowledge from a noun to a verb—knowledge is something students do, not something students have.***

The implication of Piaget's research for science education is that knowledge cannot be pre-organized and transmitted to students. Rather, knowledge must be developed through students' activity because teachers cannot transmit to students the coordination of mental activities into concepts nor do students have innate capabilities which allow immediate comprehension of meaning. Teachers verbal information can only trigger mental activity at the levels of organization which students have themselves developed (Piaget, 1973a, p. 119).

Traditional ideas of knowledge believe it to be a state formed prior to its presentation, a 'body of material' to be covered. These ideas lead to educational focus on how to present lessons, how to get and hold students' attention, at what level various concepts can be taught, what kind of activities best reinforce teaching, how to test to determine what material has been retained, and other concerns involved in the transmission of knowledge and its reception by students. Piaget's science of genetic epistemology raises different kinds of educational problems because knowledge is understood as arising from students' activity.

Table 1 summarizes some of the functions of intelligence Piaget studied to determine if knowledge is the product of a transmission and reception, if it is innate such as a basic ability to reason or observe, or if it develops from activity (what Piaget calls 'assimilation') (see *references* for citations).

Table 1

Topic and Problem	Traditional Idea	Piaget's Science of Knowledge	Implications of Piaget's Science of Knowledge
1. Perception How does perception manage to produce apparent copies of reality?	Perception or observation is a direct impression or copy of reality received through the senses and therefore the most honest data we have of an object.	Perception depends on coordinations organized by sensory motor activities which shapes, determines, and corrects what is perceived. Perception in itself lacks objectivity.	Ask students to generate and organize demonstrations, models, visuals, and their observations. Do not present demonstrations, models, or visuals to transmit knowledge.
2. Learning Does knowledge accumulate and develop from learning or does learning depend on development?	From generalization of many learning experiences, students form more abstract knowledge. Learning experiences produce development.	Learning only exercises existing methods of understanding. Development of understanding is produced by students' attempts to coordinate and organize activity and to work out its problems.	Make teaching focus on how learners organize a method, not on answers. Have students organize learning activities. Do not organize methods or completed knowledge for presentation to students.

Contributions of Piaget to Science Education			
Topic and Problem	**Traditional Idea**	**Piaget's Science of Knowledge**	**Implications of Piaget's Science of Knowledge**
3. Contradictions/ Error What is the role of errors and misconceptions produced in students' work?	Errors indicate incorrect learning of skills or content presented by teacher or text. Monitoring and corrective feedback is necessary to prevent erroneous learning.	Errors aren't failures of learning but of understanding; they are reflections of students' methods of understanding and are needed by students to see results of their attempted method.	Let students produce and 'own' results of their activities. Feedback mechanism is presentation of method and results to peers which forces auto-correction. Errors are useful results.
4. Problems What is the role of problems in promoting student growth?	Problems require practice and serve to re-enforce specific performance skill or concept application. Problems focus on producing correct answers or performances.	Growth depends not on practice of isolated skills and behaviors but on organizing activities into rational wholes or systems. Problems of method, not answer, are fundamental.	Pose problems of organization and method, not answer. Follow learning by helping students' see and pose problems raised by previous learning. Problems generate need for activity.
5. Imitation What is the role of imitation and role models in producing student growth?	Modeling, demonstrating, and showing students how to solve problems or do a procedure provides students with a clear understanding of the knowledge or procedures.	The capability to imitate or learn from a model depends on students' organization of a method for reconstructing the models' activity. This development requires a construction by students.	Have students construct the model, the procedure, or the presentation. Don't present models or show procedures to imitate unless students have prior understanding.
6. Language What is the role of language in knowledge?	Language contains and represents the logic and meaning of knowledge. By analyzing language used we can understand what it means; by learning language we can properly express thoughts.	Language does not store or transmit meaning nor does it create the representational function. Representational symbols are necessary to thought but do not form thought.	Develop understanding and meaning first in students; then provide labels for things. Do not focus on language training which does not create understanding; focus on developing students' meaning.
7. Imagery What is the role of imagery in capturing and understanding reality?	An image is the perceptual copy of the object which remains when the object is absent. An image presents an object or shows a concept so that it can be understood.	Imagery is not a direct copy and does not derive from perception. It is constructed by mental activity and incapable of promoting or developing thought since it is a product of organizing function of mental activity.	Develop imagery by having students transform objects, perform transformations in thought, and capture in drawings or diagrams. Drawings/imagery depends on thought for its construction and representations.
8. Memory How does memory work to conserve knowledge and experiences?	Information is received and encoded then stored in long or short term memory. All that is experienced is stored. The mind retrieves only partially what was placed in memory.	Memory is a reconstruction which depends on original organization of experience. Memory doesn't develop thought but is developed by thought. Memory reflects only what was understood.	Emphasize understanding over recall. Make all information available for learning and assessment. Stress active organizing of information and experiences, not storage.

Table 1: Comparison of traditional ideas, Piaget's science of genetic epistemology, and its educational implications (see annotated references for citations by category).

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The findings of genetic epistemology reveal that knowledge is not pre-organized outside learners nor is it transmitted to them through instruction, text, or from observation. The essential feature of knowledge is that it consists of the organization of activities which act on reality to modify it and therefore to know it (Piaget, 1970b, p. 15; 1973a, pp. 90, 107). Thus, external factors can support and provide stimulus for the mental activities of students but the essential work of organizing, coordinating, and fitting these activities of thought to reality can only be done by students (Piaget, 1957, p. 39; 1960, pp. 34-50; 1970b, pp. 14-16).

The fundamental switch from traditional ideas of knowledge to knowledge as systems of mental activity changes the nature of the problems, roles, and needs of science teachers. The shift from instruction which attempts to transmit completed knowledge to instruction which attempts to see and work with the systems of mental activity students naturally and actually generate, changes the nature of problems and roles of various instructional functions (Piaget, 1973b, pp. 1-37).

The source of knowledge for students does not fundamentally lie with the teacher, direct experience with objects, language, demonstrations, or visuals; the source of knowledge lies within students' organization of activity. To know does not mean to receive impressions and data from which to generalize. To know means to mentally act on the object and thereby to reconstruct the object in thought (Piaget, 1970f, pp. 10-20).

Conclusions

Understanding

If educators wish to understand and use Piaget's research showing knowledge as mental activity organized by students into systems, several important needs arise:

1. Systems -- Science educators will need clear, technical specifications and understanding of the fundamental nature and properties of systems as they are found in student activities at all levels. The understanding of systems as logico-mathematical models of thought provides a precise language for describing mental operations. Piaget found three major systems by which thought organizes its activities:
   - functional or one-way (non-reversible) systems,
   - operational or two-way (reversible) systems, and
   - formal operational or four-way (doubly reversible) (Piaget, 1957, pp. 8-37; Piaget 1970e, pp. 3-16; Piaget & Inhelder, 1969, pp. 92-151).
2. Functions and Structures -- Science educators will need precise descriptions which clearly distinguish both the functions (the 'why' expressed in Piaget's assimilation and equilibration theory) and the structures (the 'how' addressed in the functional, concrete operational, and formal operation systems) of the development of students' understanding of each key concept and the overall structure of the discipline (the basic conceptual organizers and the 'model' which relates them one to another) (Piaget, 1971A, pp. 138-185.

(a) *Functions remain constant* (what Piaget calls the 'functional invariants', the equilibration of assimilation and accommodation) (Piaget, 1952, pp 1-20) through investigation cycles. These functions include:
   - finding and identifying problems,
   - generating ideas and hypotheses,
   - formulating methods,
   - gathering data and conducting verifications,
   - analyzing the results and evaluating progress, etc. (for a complete assimilation model see Piaget, 1977, 3-77).

(b) *Structures or systems of understanding change and develop* through investigation cycles. These structures include:
   - *first preoperational methods*, pre-concepts, unstable (perceptual) data, definitions by

usage, non-logical analysis, etc.

- *then operational methods*, concepts, objective description, conceptual definitions, deductions, etc.
- *and finally, formal operational methods*, hypotheses organizing and isolating all possible variables, propositional logics, true experimental methods, explanations, etc. (Piaget, 1970d, pp. 74-76).

3. *Problems of Development* -- Science educators will need an identification of the key problems which student thinking must overcome at each stage in their development of understanding of a phenomenon. And, these problems should be related to the usefulness each discipline has in solving fundamental human problems of adaptation since knowledge is itself an expression of the adaptation of thought to reality (Piaget, 1960, pp. 7-17).
   - For example, problems of classification and description form initial Stage I problems producing laws and facts which allow simple predictions and generalizations.
   - As understanding advances to Stage II, the problems of description and conceptualization shift to deeper problems of relationships which allow the deduction of laws and the formulation of logical or mathematical systems.
   - Finally, in Stage III, problems of explanation arise from the natural progression to attempt to understand and find the reason for things which allows the construction of a causal model (Piaget, 1970d, pp. 73-76; 1972, pp. 20-51, 78-81).

4. *Psychological Facts* -- Science educators will need factual descriptions of what the actual systems of mental operations will look like at each stage of development (Piaget, 1973b, pp. 21-23). When student investigation begins, teachers must have a clear idea of:
   - what to expect from students,
   - how to differentiate between learning or socialization effects in students' behavior, and their systems of understanding and conception, and
   - clear examples of how students reason and organize their activity at each stage of development.

   These psychological facts will assist teachers in determining exactly what a concept means to students at every level of development (see texts listed in reference section for many descriptions of students' activity).

5. *Factors of Development* -- Science educators will need knowledge of the role various factors play in the development of students' knowledge. To make student development rather than simple learning the goal of education, the intellectual functions used in learning cannot be taken for granted. Information about the development of functions and their role in student cognitive development will need to be made available to teachers. These functions include:
   - memory,
   - language,
   - teacher explanation,
   - pre-organized laboratory activities,
   - student analysis and reflection,
   - social interaction and cooperative learning,
   - textbooks,
   - experiments organized and performed on objects, etc.

   Science educators will need precise understanding of the proper roles of the various functions in promoting the development of student understanding (Piaget 1971c, 45-67; 1976, 332-353).

Teaching Applications

Piaget's scientific understanding of the knowledge of the science curriculum, which allows educators to see and work with the development of students' systems of mental activity, leads to a need for new techniques and methods of teaching.

1. *Student Research Problems* -- Science teachers will need effective activities and methods which help students find and formulate problems of investigation which are specially fitted to helping students develop understanding of the concepts of the curriculum. These have to do with specific techniques for getting student activity started and working with what students initiate to help them find an interesting, clear, and purposeful direction for their learning activities.

2. *Methods of Investigation* -- Science teachers will need methods and materials which allow them to work with students' activity as it develops rather than with presenting knowledge. These must assist and develop in students their ability to organize their learning activities. Development occurs when many learning activities form cycles so as to successively build on previous learning and follow the natural development of a system of understanding.

3. *Data and Learning Results* -- Science teachers will need rich data sources for students' use both in the form of actual objects and phenomena, and in representational sources (written and visual). Science teachers will need corresponding methods and strategies which make effective use of student learning activity. Instead of carefully organized textbooks and laboratory procedures, instructional methods featuring student development require that students organize investigations and previous learnings into coherent understandings and explanations.

4. *Qualitative Assessments* -- Science teachers will need qualitative methods which help students display their own development of understanding so as to establish student feedback mechanisms within the classroom. Institutional methods of assessment and evaluation must provide the objective description and explanation of the development of students' systems of understanding as seen in the actual products of learning activities. These assessment methods must be clearly distinguished from students' own interests in self-evaluation and self corrections.

Thus educational practice and understanding can be expected to follow the same fundamental path of all practical activity and cognitive development. It begins with an initial awareness and ability to see only outward, observable appearances or end results, and progresses toward increasingly understanding the internal processes, methods of production, and developmental mechanisms of mental activities (Piaget, 1976, 335-337).

For educational practice, this law of development suggests that the traditional teaching focus on observable student behaviors and performances will gradually give way to instructional focus on the internal mechanisms of thought and finally to their development. Corresponding to this development will be techniques which increasingly take account of and work directly with the actual systems of mental activity students can initiate and organize in response to problems they see and address (Piaget, 1970f, 170-173).

Goals of Education

The real problem set before educators is the nature of intellectual development which education intends to produce in the future citizens of society. Does science education attempt to stock the memory and prepare citizens who follow the directions, constructions, and completed understanding of others, or does science education intend to actively pursue the intellectual development of every student so as to prepare citizens who can solve problems, who can organize and invent, who can make sense of difficult situations and organize methods of action, and in short, who have constructed an understanding such that "they are capable of production and creativity and not simply repetition?" (Piaget, 1970f; pp. 17-20; 1973b, pp. 3-37)

> ***"The goal of intellectual education is not to know how to repeat or retain ready-made truths (a truth that is parroted is only a half-truth). It is learning to master the truth by oneself at the risk of losing a lot of time and of going through all the roundabout ways that are inherent in real activity" (Piaget, 1973b, p. 106).***

The ideal for science education is to increasingly understand and affect the fundamental intellectual development of students. This supposes the movement away from traditional, transmission methods of teaching which

appeal to the illusion that knowledge can be presented and transmitted ready made to students.

It is true traditional methods produce immediate performance effects in students. However, it is the intellectual development of students which has the long range effect of promoting understanding and counts for most. Piaget's science of knowledge provides both a scientific basis for science educators who wish to understand student development and an ideal for attempts to fashion educational methods which ***"organize situations that create useful problems for students and discussion which creates the need for reflection and reconsideration...What is desired is that the teacher cease being a lecturer, satisfied with transmitting ready-made solutions; his role should rather be that of a mentor stimulating initiative and research...This obviously leads to placing all educational stress on the spontaneous aspects of students' activity" (Piaget, 1973, pp. 11, 16).***

References

(An asterisk indicates a cited work. Numbers correspond to numbers in Table 1. Some texts appear twice.)

1. PERCEPTION:

1969a. Piaget, Jean. ***Mechanism of Perception***. Translated by Gavin Nott Seagrim. New York: Basic Books. Provides a summary of the technical research showing how intelligence provides the necessary organizing relations out of perceptual stimuli to create a perceptual 'field' or whole. Perception is not static and distinct from the operational compositions of intelligence nor is perception the source of knowledge since perception always depends on intelligence for the construction of the whole as perceived. Direct perception is often highly distorted and misleading since it is uncorrected appearance. Final three chapters provide an excellent summary and conclusions.

2. LEARNING:

1974. Inhelder, Bärbel; Sinclair, Hermine; and Bovet, Magali. ***Learning and the Development of Cognition***. Translated by Susan Wedgwood. Cambridge: Harvard University Press. Directly addresses the problem of how understanding develops, whether fundamentally dependent on learning or on development (the latter is the case). Also shows the integrated nature of the development of understanding since concepts interact in a complex manner (e.g., measurement is not simply the application of number but forms a parallel and interactive development of its own).

3. CONTRADICTIONS/ERRORS:

1980a. Piaget, Jean. ***Experiments in Contradiction***. Translated by Derek Coltman. Chicago: University of Chicago Press. Since it is disequilibrium which drives development, it is easy to assume contradictions are the source of development. This research text shows that contradiction is not the source of disequilibrium nor of development but that the capability to see a contradiction itself depends on the development of a system of logic.

4. PROBLEMS:

*1976. Piaget, Jean. *Grasp of Consciousness*. Translated by Susan Wedgwood. Cambridge: Harvard University Press. Addresses when and how awareness takes place. Shows conscious awareness of problems and their solutions involves a construction and is a reconstruction of activity in thought. Awareness is thus not a simple illumination of activity but involves a development of its own, beginning with the most peripheral appearances and proceeding to 'seeing' the 'how' which produces the outward appearances.

1978. _____. ***Success and Understanding.*** Translated by Arnold J. Pomerans. London: Routledge & Kegan Paul. Addresses the relationship between overcoming problems of technique (know how) leading to practical activity (success), and understanding activity in thought. Shows how the reconstruction of activity as thought may initially lag behind successful action and even misrepresent action, while later, thought far outstrips action.

5. Imitation, 6. Language, and 7. Imagery:

*1973a. Piaget, Jean. ***Child and Reality: Problems of Genetic Psychology.*** Translated by Arnold Rosin. New York: Grossman. Chapter 6 shows that language does not contain or even completely reflect the rational systems of thought or meaning of which it forms the representational aspect. Language depends on the formation of meaning and therefore the coordination of mental activity but does not itself provide the coordinations of rational thought. Language is only the figurative aspect of thought and does not compose the operative aspect.

1967. _____. ***Six Psychological Studies.*** Translated by David Elkind and Anita Tenzer. New York: Random House. Chapter 3 describes the development of language and its relationship to thought. Thought precedes language. Language confines itself to helping thought by providing it with its representations thus allowing its evocation of absent situations initially through imitations, symbols, and finally language itself.

1971. Piaget, Jean, and Inhelder, Bärbel. ***Mental Imagery in the Child: A Study of the Development of Imaginal Representation.*** Translated by P. A. Chilton. New York: Basic Books. Reports research which shows the active nature of intelligence in constructing images and refutes the notion that the image is simply a copy of the object. What we 'see' as reality actually consists of a construction organized by a system of transformations developed by intelligence.

*1969. _____. ***Psychology of the Child.*** Translated by Helen Weaver. New York: Basic Books. Chapter 3 presents the "semiotic or symbolic function" to show its development from deferred imitation which starts after the disappearance of the model, to symbolic play, to graphic images, to mental image, and finally to verbal evocation of events which are not occurring at the time. The role of language is only to detach thought from behavioral action by its representation and not to develop meaning and thought.

8. Memory:

1973. Piaget, Jean, and Inhelder, Bärbel. ***Memory and Intelligence.*** Translated by Arnold J. Pomerans. New York: Basic Books. This research text shows how memory, far from being simply a placement into long or short term storage, is actually a reconstruction of experience by the use of organization provided by intelligence. Thus, we remember what we understand. The development of intelligence enriches the powers of memory even with no intervening experiences while at early stages what is remembered may actually be erroneous.

The Development of Students' Activity:

The following research texts all show how activity develops at the sensory motor level to be reconstructed on the plane of thought as the basic concepts of space, time, object, movement, and so forth. In each instance the concepts recapitulate the formation of a system of operations having the same analogous forms as logic does in its classification (concepts) and seriation (relations) systems.

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1958. Inhelder, Bärbel and Piaget, Jean. ***Growth of Logical Thinking From Childhood To Adolescence: An Essay on the Construction of Formal Operational Structures.*** Translated by Anne Parsons and Stanley Milgram. Basic Books. An essential research text for science educators. Shows and explains the basic laws of development as thought organizes its operations into conceptual systems and then reconstructs the conceptual systems as 'variables' organized by a far richer, formal, hypothetical deductive logic.

1964. _____. ***Early Growth of Logic in the Child: Classification and Seriation.*** Translated by Eric A. Lunzer and D. Papert. New York: Harper & Row. A classic, essential research text describing the fundamental principles of concept and relation formation in students. There is perhaps no social scientific phenomena more stable and fundamental than students' classification systems displayed in these studies.

1970a. Piaget, Jean. ***The Child's Conception of Movement and Speed.*** Translated by G.E.T. Holloway and M.J. MacKenzie. Basic Books. Presents the development of concepts of movement and speed from their origins in displacement actions of objects.

1969b. _____. ***The Child's Conception of Time.*** Translated by Arnold J. Pomerans. Basic Books. Repeats the pattern of Piaget's classic conservation studies to show the conservation of time as a concept which is developed by students' mental activity. Shows temporal systems (durations and order of events) are analogous to classification and seriation.

*1977. _____. ***Development of Thought: Equilibration of Cognitive Structures.*** Studies in Genetic Epistemology, vol. 33. Translated by Arnold Rosin. New York: Viking Press. Provides the explanation of the development of thought as the equilibration of the various functions found within mental activity. If knowledge does not come from learning experiences, language transmissions, biological maturation of innate capabilities, then the fundamental developmental factor lies within the self-regulating qualities of living activity, that of the equilibration of the forms of activities the organism generates and the modifications of those forms by the external reality which the activity assimilates.

*1952. _____. ***Origins of Intelligence in Children.*** Translated by Margaret Cook. New York: International Universities Press, Inc. Lays out the fundamental theories of the formation of sensory motor intelligence and the mechanism of mental assimilation. The introduction is particularly important in defining the question of the relationship between mind and biological organization. Any theory of intelligence must explain how biological functioning is able to eventually produce the systems of intelligent thought which forms the mind.

1974. Piaget, Jean, and Garcia, Rolando. ***Understanding Causality.*** Studies in Genetic Epistemology, vol. 26. Translated by Donald and Marguerite Miles. New York: W.W. Norton & Co. A rich source for the study of students' developing conceptions of all sorts of phenomena—heat, light, sound, energy, work, transmission of forces, vectors of forces, changes in states of matter, etc. These studies describe the development of students' understanding to arrive at causal explanations as an invariance through transformations of objects. Must reading for every science educator.

1977. Piaget, Jean; Grize, Blaise; Szeminska, Alina; and Bang, Vinh. ***Epistemology and Psychology of Functions.*** Studies in Genetic Epistemology, vol. 23. Translated by A. Sunier. Boston: D. Reidel Publishing Co. Describes research on pre-operational reasoning, called 'constituting functions', in young children. Shows howthe one-way operations form categories and 'morphisms' in early thought.

1967. Piaget, Jean, and Inhelder, Bärbel. ***The Child's Conception of Space.*** Translated by F.J. Langdon and J.L. Lunzer. W.W. Norton. Another example of how activity develops to construct a concept of reality, the spatial object. Shows the development of concrete operations of classification and seriation as they appear as spatial operations to form concepts of space.

1974. _____. ***The Child's Construction of Quantities.*** Translated by Arnold J. Pomerans. Basic Books. A classic introductory research text showing the conservation phenomena produced by the development of concrete operations, in this case, in the concepts of quantity, weight, volume, and density. Provides a clear verification of the fundamental importance of the formation of mental operations into systems as the method for constituting a concept.

1975. _____. ***The Origin of the Idea of Chance in Children.*** Translated by Lowell Leake, Jr., Paul Burrell, and Harold D. Fishbein. W W Norton. Shows how students naturally develop understanding and distinctions between chance events and those having underlying causal relationships. Covers the development of chance, probability, correlations, combinations, and permutations.

1960. Piaget, Jean; Inhelder, Bärbel; and Szeminska, Alina. ***The Child's Conception of Geometry.*** Translated by E.A. Lunzer. Basic Books. An in-depth follow-on study to the research on the development of spatial understanding. A rich source of information regarding basic concepts of points, lines, planes, coordinate systems, measurements, angles, and so forth. Perhaps in no other area does Piaget have so direct yet so under-utilized a contribution to make to education as in the area of geometry and spatial reasoning.

1952. Piaget, Jean, and Szeminska, Alina. ***The Child's Conception of Number.*** Translated by Caleb Gattegno and Frances Mary Hodgson. Humanities Press. Another classic text often referenced but poorly understood. Shows how the fundamental basis of number rests in the development of a qualitative system of logic which organizes both classification and seriation into number. Again, shows the fundamental importance of the activities and operations of thought in constituting the elements and numbers and not the reverse.

DEVELOPMENTAL PSYCHOLOGY:

1967. Piaget, Jean. ***Six Psychological Studies.*** Translated by David Elkind and Anita Tenzer. New York: Random House. Covers general aspects of mental development, structures, genetic epistemology, psychology of intelligence, and language. Of central concern in a theory of development is the concept of equilibrium which is presented in chapter IV.

*1960. _____. ***Psychology of Intelligence.*** Translated by Malcom Piercy and Daniel Ellis Berlyne. Totowa, New Jersey: Littlefield, Adams and Co. Perhaps one of the best introductory texts to Piaget's theories. Uses dated language but addresses fundamental problems and theories being debated today. Discusses the importance and theory of systems and the differences between behavior, intuition, and rational thought. 'Must' reading.

*1969. Piaget, Jean, and Inhelder, Bärbel. ***Psychology of the Child.*** Translated by Helen Weaver. New York: Basic Books. Presents a simply written synthesis and summary of the work of Piaget and Inhelder. Discusses the development of sensory motor activity up through formal thought and how the development of activity affects perception, language functions, and affectivity.

GENETIC EPISTEMOLOGY:

1980b. Piaget, Jean. ***Adaptation and Intelligence: Organic Selection and Phenocopy.*** Translated by Stewart Eames. Chicago: University of Chicago Press. A short, follow-on text to *Biology and Knowledge* to dispel common misinterpretations. Provides a clear explication of the parallel theory of biological evolution which corresponds to equilibration theory of knowledge. Refutes both Lamarkianism and Darwinism in both biology and their equivalents in psychology. Piaget is neither a maturationist nor an empiricist.

*1971a. _____. ***Biology and Knowledge: An Essay on the Relations Between Organic Regulations and Cognitive Processes.*** Translated by Beatrix Walsh. Chicago: University of Chicago Press. Heavy duty text which develops the thesis that knowledge is simply an advanced form of the adaptation of human activity to external reality. Knowledge is a form of biological adaptation subject to the very same mechanism of development as biological evolution which also is an equilibration of activity between the structures of the organism and the environment. Behavior and activity are the sources of evolution, not chance mutation and selection. Life is essentially autoregulation.

*1973a. _____. ***Child and Reality: Problems of Genetic Psychology.*** Translated by Arnold Rosin. New York: Grossman. Discusses common problems of developmental psychology and the growth of knowledge.

*1970b. _____. ***Genetic Epistemology.*** Translated by Eleanor Duckworth. Columbia University Press. Short and very simply written overview of genetic epistemology without technical language (actually a series of four lectures delivered in the U.S.) explaining the fundamental problem of the origins of knowledge using examples in the areas of mathematics, space, time, language.

1970c. _____. "Piaget's Theory." Translated by Guy Cellerier and Jonas Langer. In ***Carmichael's Manual of Child Psychology***, Vol. 1, 3rd ed., pp. 703-32. Edited by Paul H. Mussen. John Wiley & Sons, 1970c. Excellent, technical summary laying out the fundamental concepts of Piaget's theory of development in his own words. Addresses the relation between the subject and object, assimilation and accommodation, stages, relations between development and learning, the operative and figurative aspects, factors of development, equilibration and cognitive structures, and the logico-mathematical aspects of structures.

*1970d. _____. ***Place of the Sciences of Man in the System of Sciences.*** New York: Harper and Row; Harper Torchbooks for UNESCO. A short, insightful text of considerable use to science teachers for its definitions of science and the various disciplines, and principles, mechanisms, and stages of scientific progress.

*1972. _____. ***Principles of Genetic Epistemology.*** Translated by Wolfe Mays. New York: Basic Books. Another short, excellent text providing an overview. Foundational text for anyone wanting a clear understanding of Piaget's science of knowledge.

*1971c. _____. ***Psychology and Epistemology.*** Translated by Arnold Rosin. New York: Grossman. Shows how developmental psychology provides a tool to scientifically answer questions of epistemology. Clarifies the fundamental problem of the source of knowledge and shows specific instances of how the problem is researched. Distinguishes between the proper domains and definitions of science and philosophy.

1988. Piaget, Jean, and Garcia, Rolando. ***Psychogenesis and the History of Science.*** Translated by Helga Feider. Columbia University Press. The result of the studies in causality. Shows that the stages in the development of students' understanding of various causal explanations recapitulates in structural form the stages in the history of science and algebra. Very important model for science education methods.

STRUCTURES (SYSTEMS):

*1957. Piaget, Jean. ***Logic and Psychology.*** Translated by Wolfe Mays and Frederick Whitehead. New York: Basic Books. A very short, concise text providing a simplified introduction to the technical points of various psycho-logics which are used to describe the mental operations of thought.

*1960. _____. ***Psychology of Intelligence.*** Translated by Malcom Piercy and Daniel Ellis Berlyne. Totowa, New Jersey: Littlefield, Adams and Co. Written around the time of the development of the theory of groupings, this text provides a less technical explanation of groupings and structures than found in later texts. See chapter II for an excellent introduction to cognitive structures.

*1970e. _____. ***Structuralism.*** Translated by Chaninah Maschler. New York: Basic Books. It is hard for Americans to appreciate the great interest in and importance of structuralism in Europe. This text shows the fundamental importance of structuralism as a method in the study of all human productions, social, mathematical, scientific, linguistics, etc. In chapter 1 it provides three fundamental distinguishing characteristics of all structures.

EDUCATION:

*1970f. _____. ***Science of Education and the Psychology of the Child.*** Translated by Derek Coltman. New York: Grossman Publishers. Reviews the state of education and shows why students' activity must be the philosophic basis for education.

*1973b. _____. ***To Understand is to Invent: The Future of Education.*** Translated by George-Anne Roberts. Viking Press for UNESCO. Lays out an ethics for education as part of UNESCO's Universal Declaration of Human Rights. A second part concerns the structural foundations of education.

OTHER WORKS:

1971b. _____. ***Insights and Illusions of Philosophy.*** Translated by Wolfe Mays. New York: Meridian. Lays out the proper role of philosophy as opposed to science. Philosophy is a wisdom which does not prescribe limits or methods to science nor is philosophy a 'higher' form of knowledge. Philosophy is a coordination of values.

1981. _____. ***Intelligence and Affectivity: Their Relationship During Child Development.*** Annual Reviews Monograph, ed. Mark R. Rosenzweig. Translated by T. A. Brown and C. E. Kaegi. Palo Alto, Cal.: Annual Reviews. A short text compiled from Piaget's lectures on the development and role of the affective component in all activity and knowledge. Provides the stages of affective development.

Oregon Department of Education
700 Pringle Parkway, SE
Salem, OR 97310-0290

Verne A. Duncan
State Superintendent
of Public Instruction

Oregon Schools . . . . . A Tradition of Excellence!

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